

PRETREATMENT 101

**CONTINUING EDUCATION
PROFESSIONAL DEVELOPMENT COURSE**
30 PDHs OR 3 CEUs or 30 Contact Hours upon completion



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Conventional Pollutants

BOD, TSS, fecal coliform, oil and grease, and pH

In the above photo, sampling equipment after being washed and being allowed to air dry. You as a Sampler will spend up to 1-2 hours a day preparing your sample bottles. This may include washing your sample tools, bottles and other equipment. Some bottles will need to be washed in a three or four step process. Hydrochloric and other acids are used for the cleaning of glass bottles. The Pickle or large jar is often re-used and washed on a daily basis.

Pretreatment Inspectors and Stormwater Inspectors will often work in pairs. Usually one Inspector will spend a lot of time setting up automatic samplers and programming flow meters, while the other Inspector will calibrate pH meters and related laboratory equipment, pre-preserve sample bottles, gather ice and calibrate the safety equipment and gas meters.

Some POTWs will hire both Samplers and Inspectors and split these duties up. Other POTWs will utilize Inspectors as Samplers.



Parshall Fume and Ultrasonic Flow Meter.

Notice the debris, most POTW's will write a NOV for uncleanness, the POTW's that do write NOV's will usually not have an ordinance in place.



Professor Melissa Durbin in her water quality/pollution control days as a pretreatment inspector. Since then she has taught thousands of operators the skills necessary to become an effective inspector.

Technical Learning College's Scope and Function

Technical Learning College (TLC) offers affordable continuing education for today's working professionals who need to maintain licenses or certifications. TLC holds approximately eighty different governmental approvals for granting of continuing education credit.

TLC's delivery method of continuing education can include traditional types of classroom lectures and distance-based courses or independent study. Most of TLC's distance based or independent study courses are offered in a print based format and you are welcome to examine this material on your computer with no obligation. Our courses are designed to be flexible and for you to finish the material at your leisure. Students can also receive course materials through the mail. The CEU course or e-manual will contain all your lessons, activities and assignments. Most CEU courses allow students to submit lessons using e-mail or fax; however some courses require students to submit lessons by postal mail. (See the course description for more information.) Students have direct contact with their instructor—primarily by e-mail. TLC's CEU courses may use such technologies as the World Wide Web, e-mail, CD-ROMs, videotapes and hard copies. (See the course description.) Make sure you have access to the necessary equipment before enrolling, i.e., printer, Microsoft Word and/or Adobe Acrobat Reader. Some courses may require proctored exams depending upon your state requirements.

Flexible Learning

At TLC, there are no scheduled online sessions you need contend with, nor are you required to participate in learning teams or groups designed for the "typical" younger campus based student. You will work at your own pace, completing assignments in time frames that work best for you. TLC's method of flexible individualized instruction is designed to provide each student the guidance and support needed for successful course completion.

We will beat any other training competitor's price for the same CEU material or class-room training. Student satisfaction is guaranteed.

Course Structure

TLC's online courses combine the best of online delivery and traditional university textbooks. Online you will find the course syllabus, course content, assignments, and online open book exams. This student-friendly course design allows you the most flexibility in choosing when and where you will study.

Classroom of One

TLC Online offers you the best of both worlds--you learn on your own terms, on your own time, but you are never on your own. Once enrolled, you will be assigned a personal Student Service Representative who works with you on an individualized basis throughout your program of study. Course specific faculty members are assigned at the beginning of each course providing the academic support you need to successfully complete each course.

Satisfaction Guaranteed

Our Iron-Clad, Risk-Free Guarantee ensures you will be another satisfied TLC student.

We have many years of experience, dealing with thousands of students. We assure you, our customer satisfaction is second to none. This is one reason we have taught more than 20,000 students.

Our administrative staff is trained to provide outstanding customer service. Part of that training is knowing how to solve most problems on the spot.

TLC Continuing Education Course Material Development

TLC's continuing education course material development was based upon several factors; extensive academic research, advice from subject matter experts, data analysis, task analysis and training needs assessment process information gathered from other states.



We teach this course in both a conventional classroom setting and in a distance based educational CEU course. We welcome you to download and complete the assignment in Microsoft Word. Simply complete the course assignment and simply fax or e-mail your assignment back to us.

CEU Course Description

PRETREATMENT 101 CEU TRAINING COURSE

Intended Audience

Stormwater Inspectors, Wastewater Treatment Operators, Pretreatment and Industrial Waste Inspectors--the target audience for this course is the person interested in working in the stormwater/pretreatment field, wastewater treatment or pretreatment/industrial wastewater facility, wishing to maintain CEUs for certification license, wanting to learn how to do the job safely and effectively, and/or to meet education needs for promotion. This CEU Course will review the Environmental Protection Agency's Rules and Regulation relating to Title 40 Code of Federal Regulations, Part 403, "*General Pretreatment Regulations for Existing and New Sources of Pollution*," and other applicable State and Federal laws, including but not limited to, the Clean Water Act and the Industrial Pretreatment 40 CFR. This course will cover the fundamentals and basic requirements of the Federal rule concerning the National Pretreatment Rule, POTW, wastewater sampling and reporting information.

Final Examination for Credit

Opportunity to pass the final comprehensive examination is limited to three attempts per course enrollment.

Course Procedures for Registration and Support

All of Technical Learning College's distance learning courses have complete registration and support services offered. Delivery of services will include, e-mail, web site, telephone, fax and mail support. TLC will attempt immediate and prompt service.

When a student registers for a distance or correspondence course, he/she is assigned a start date and an end date. It is the student's responsibility to note dates for assignments and keep up with the course work. If a student falls behind, he/she must contact TLC and request an end date extension in order to complete the course. It is the prerogative of TLC to decide whether to grant the request.

All students will be tracked by their social security number or a unique number will be assigned to the student.

Instructions for Written Assignments

The Pretreatment 101 CEU Training course uses a multiple-choice style answer key.

Feedback Mechanism (examination procedures)

Each student will receive a feedback form as part of his or her study packet. You will find this form in the rear of the course or lesson.



Security and Integrity

All students are required to do their own work. All lesson sheets and final exams are not returned to the student to discourage sharing of answers. Any fraud or deceit and the student will forfeit all fees and the appropriate agency will be notified.

Grading Criteria

TLC will offer the student either pass/fail or a standard letter grading assignment. If TLC is not notified, you will only receive a pass/fail notice.

Required Texts

The Pretreatment 101 CEU Training course comes complete with the Environmental Protection Agency's Rules and Regulation relating to Title 40 Code of Federal Regulations, Part 403, "General Pretreatment Regulations for Existing and New Sources of Pollution," and other applicable State and Federal laws, including but not limited to, the Clean Water Act and Industrial Pretreatment 40 CFR.

This course will cover the fundamentals and basic requirements of the federal rule concerning pretreatment, POTW, SIU responsibilities, wastewater sampling and reporting information.

Recordkeeping and Reporting Practices

TLC will keep all student records for a minimum of seven years. It is the student's responsibility to give the completion certificate and any other forms to the appropriate agencies. TLC will not release any records to any other party.

ADA Compliance

TLC will make reasonable accommodations for persons with documented disabilities. Students should notify TLC and their instructors of any special needs. Course content may vary from this outline to meet the needs of this particular group.

Mission Statement

Our only product is educational service. Our goal is to provide you with the best possible education service possible. TLC will attempt to make your learning experience an enjoyable opportunity.

Educational Mission**The educational mission of TLC is:**

To provide TLC students with comprehensive and ongoing training in the theory and skills needed for the environmental education field,

To provide TLC students with opportunities to apply and understand the theory and skills needed for operator certification,

To provide opportunities for TLC students to learn and practice environmental educational skills with members of the community for the purpose of sharing diverse perspectives and experience,

To provide a forum in which students can exchange experiences and ideas related to environmental education,

To provide a forum for the collection and dissemination of current information related to environmental education, and to maintain an environment that nurtures academic and personal growth.

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In this photo, the Chemist is waiting for the Sampler to return with samples. You can see the small refrigerator with a lock on it. Samplers will normally release the samples to the Chemist, but if the Chemist is out of the office, or after work hours, you will place the samples in the refrigerator and lock it. Write on your chain-of-custody report that you placed the samples in the locked refrigerator.

Chain-of-Custody (COC)

A record of each person involved in the possession of a sample from the person who collects the sample to the person who analyzes the sample in the laboratory.

Important Information about this Manual

This manual has been prepared to help students gain or increase awareness of the Environmental Protection Agency's Rules and Regulation relating to Title 40 Code of Federal Regulations, Part 403, "**General Pretreatment Regulations for Existing and New Sources of Pollution**," and other applicable State and Federal laws, including but not limited to, the Clean Water Act, Industrial pretreatment 40 CFR. This course will cover the fundamentals and basic requirements of the federal rule concerning the national pretreatment rule, POTW, wastewater sampling and reporting information.

The scope of the material is quite large, requiring a major effort to bring it under control. Employee health and safety, as well as that of the public, depends upon careful application of federal and state regulations and safe working procedures. This manual will cover federal laws, regulations, required procedures and work rules relating to general pretreatment and wastewater sampling. It should be noted, however, that the federal and state regulations are an ongoing process and subject to change over time. For this reason, a list of resources is provided to assist in obtaining the most up-to-date information on various subjects and regulations

This manual is an educational document for employees who are involved with water quality and pollution control. It is not designed to meet the full requirements of the United States Environmental Protection Agency (EPA) or the Department of Labor-Occupational Safety and Health Administration (OSHA), or your State pretreatment rules and regulations. This course manual will provide general guidance and should not be used as a basis for developing general pretreatment, enforcement, reporting or wastewater sampling plans. This document is not a detailed pretreatment, pollution control, pollution prevention, wastewater treatment textbook or a comprehensive source book on water/wastewater rules and regulations.

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Monthly Average

The arithmetic average value of all samples taken in a calendar month for an individual pollutant parameter. The monthly average may be the average of all grab samples taken in a given calendar month, or the average of all composite samples taken in a given calendar month.

Preface

The industrial boom in the United States during the 1950s and 60s brought with it a level of pollution never before seen in this country. Scenes of dying fish, burning rivers, and thick black smog engulfing major metropolitan areas were images and stories repeated regularly on the evening news. In December of 1970, the President of the United States created the U.S. Environmental Protection Agency (**EPA**) through an executive order in response to these critical environmental problems.

In 1972, Congress passed the Clean Water Act (**CWA**) to restore and maintain the integrity of the nation's waters. Although prior legislation had been enacted to address water pollution, those previous efforts were developed with other goals in mind. For example, the 1899 Rivers and Harbors Act protected navigational interests while the 1948 Water Pollution Control Act and the 1956 Federal Water Pollution Control Act merely provided limited funding for State and local governments to address water pollution concerns on their own.

The CWA required the elimination of the discharge of pollutants into the nation's waters and the achievement of fishable and swimmable water quality levels. The EPA's National Pollutant Discharge Elimination System (**NPDES**) Permitting Program represents one of the key components established to accomplish this feat.

The NPDES program requires that all point source discharges to waters of the U.S. (i.e., "**direct discharges**") must be permitted. To address "**indirect discharges**" from industries to Publicly Owned Treatment Works (**POTWs**), the EPA, through CWA authorities, established the National Pretreatment Program as a component of the NPDES Permitting Program. The National Pretreatment Program requires industrial and commercial dischargers to treat or control pollutants in their wastewater prior to discharge to POTWs.

In 1986, more than one-third of all toxic pollutants entered the nation's waters from publicly owned treatment works (**POTWs**) through industrial discharges to public sewers. Certain industrial discharges, such as slug loads, can interfere with the operation of POTWs, leading to the discharge of untreated or inadequately treated wastewater into rivers, lakes, etc. Some pollutants are not compatible with biological wastewater treatment at POTWs and may pass through the treatment plant untreated.

This "**pass through**" of pollutants impacts the surrounding environment, occasionally causing fish kills or other detrimental alterations of the receiving waters. Even when POTWs have the capability to remove toxic pollutants from wastewater, these toxins can end up in the POTW's sewage sludge, which in many places is land applied to food crops, parks, or golf courses as fertilizer or soil conditioner.

The National Pretreatment Program is unique in that the General Pretreatment Regulations require all large POTWs (i.e., those designed to treat flows of more than 5 million gallons per day) and smaller POTWs with significant industrial discharges to establish local pretreatment programs. These local programs must enforce all national pretreatment standards and requirements in addition to any more stringent local requirements necessary to protect site-specific conditions at the POTW.

More than 1,500 POTWs have developed and are implementing local pretreatment programs designed to control discharges from approximately 30,000 significant industrial users. Since 1983, the Pretreatment Program has made great strides in reducing the discharge of toxic pollutants to sewer systems and to waters of the U.S. In the eyes of many, the Pretreatment Program, implemented as a partnership between the EPA, States, and POTWs, is a notable success story in reducing impacts to human health and the environment. These strides can be attributed to the efforts of many Federal, State, local, and industrial representatives who have been involved with developing and implementing the various aspects of the Pretreatment Program.

The EPA has supported the Pretreatment Program through development of numerous guidance manuals. The EPA has released more than 30 manuals that provide guidance to the EPA, States, POTWs, and industry on various pretreatment program requirements and policy determinations. Through the EPA's guidance, the Pretreatment Program has maintained national consistency in interpretation of the regulations. Nevertheless, turnover in pretreatment program staff has diluted historical knowledge, leaving new staff and other interested parties unaware of existing materials.

The intent of this correspondence course, *Pretreatment 101*, is to:

- (1) provide a reference for anyone interested in understanding the basics of pretreatment program requirements, *and*
- (2) provide a roadmap to additional and more detailed guidance materials for those trying to implement specific elements of the Pretreatment Program.

While the Pretreatment Program has demonstrated significant reductions in pollutants discharged to POTWs, Congress' goals of zero discharge of toxic pollutants and fishable/swimmable water quality have not been realized. The EPA is currently working to establish more cost-effective and common sense approaches to environmental protection (e.g., using watershed, streamlining, and reinvention concepts), creating new responsibilities for all those involved in the National Pretreatment Program. Many current challenges remain, while many new ones likely lie ahead.

This course is intended to provide an understanding of the basic concepts that drive the Program, the current status of the Program and program guidance, and an insight into what the future holds for all those involved with implementing the Pretreatment Program.



Two lab techs examine various samples, including QA/QC and Trip Blanks to ensure both sample integrity and lab equipment/sample equipment quality.

List of Pretreatment Acronyms used in this Course

Acronym Full Phrase

AA	Approval Authority
AO	Administrative Order
BAT	Best Available Technology Economically Achievable
BCT	Best Conventional Pollutant Control Technology
BMP	Best Management Practices
BMR	Baseline Monitoring Report
BOD5	5-day Biochemical Oxygen Demand
BPJ	Best Professional Judgment
BPT	Best Practicable Control Technology Currently Available
CA	Control Authority
CFR	Code of Federal Regulations
CIU	Categorical Industrial User
CSO	Combined Sewer Overflow
CWA	Clean Water Act (formerly referred to as the Federal Water Pollution Control Act or Federal Water Pollution Control Act Amendments of 1972) Pub. L. 92-500, as amended by Pub. L. 95-217, Pub. L. 95-576, Pub. L. 96-483, Pub. L. 97-117, and Pub. L. 100-4, 33 U.S.C. 1251 et seq.
CWF	Combined Wastestream Formula
CWT	Centralized Waste Treater
DMR	Discharge Monitoring Report
DSE	Domestic Sewage Exclusion
DSS	Domestic Sewage Study
ELG	Effluent Limitations Guideline
EPA	Environmental Protection Agency
EPCRA	Emergency Preparedness and Community Right to Know Act
ERP	Enforcement Response Plan
FDF	Fundamentally Different Factors
FR	Federal Register
FWA	Flow Weighted Average
GPD	Gallons per Day
IU	Industrial User
LEL	Lower Explosive Limit
MAHL	Maximum Allowable Headworks Loading
MAIL	Maximum Allowable Industrial Loading
MGD	Million Gallons per Day
MSDS	Material Safety Data Sheet
NAICS	North American Industry Classification System (replaces SIC coding in 1998)
NOV	Notice of Violation
NPDES	National Pollutant Discharge Elimination System
NRDC	Natural Resources Defense Council
NSPS	New Source Performance Standard

O&G	Oil and Grease
O&M	Operations and Maintenance
OCPSPF	Organic Chemicals, Plastics, and Synthetic Fibers
P2	Pollution Prevention
PCI	Pretreatment Compliance Inspection
PCS	Permit Compliance System
PIRT	Pretreatment Implementation Review Task Force
POTW	Publicly Owned Treatment Works
PSES	Pretreatment Standards for Existing Sources
PSNS	Pretreatment Standards for New Sources
QA/QC	Quality Assurance/Quality Control
RCRA	Resource Conservation and Recovery Act
SIC	Standard Industrial Classification
SIU	Significant Industrial User
SPCC	Spill Prevention Control and Countermeasures
SNC	Significant Noncompliance
SSO	Sanitary Sewer Overflow
SUO	Sewer Use Ordinance
TCLP	Toxicity Characteristic Leaching Procedure
TIE	Toxicity Identification Evaluation
TOMP	Toxic Organic Management Program
TRE	Toxicity Reduction Evaluation
TRI	Toxic Release Inventory
TSS	Total Suspended Solids
TTO	Total Toxic Organics
USC	United States Code
UST	Underground Storage Tank
WET	Whole Effluent Toxicity
WWTP	Wastewater Treatment Plant



Glossary of Terms

This glossary includes a collection of terms used in this course and an explanation of each term.

Act or “the Act” [40 CFR §403.3(b)]

The Federal Water Pollution Control Act, also known as the Clean Water Act, as amended, 33 USC 1251 *et seq.*

Approval Authority [40 CFR §403.3(c)]

The Director in an NPDES State with an approved State Pretreatment Program and the appropriate EPA Regional Administrator in a non-NPDES State or State without an approved pretreatment program.

Approved POTW Pretreatment Program or Program [40 CFR §403.3(d)]

A program administered by a POTW that meets the criteria established in 40 CFR Part 403 and which has been approved by a Regional Administrator or State Director.

Approved State Pretreatment Program

A program administered by a State that meets the criteria established in 40 CFR §403.10 and which has been approved by a Regional Administrator

Approved/Authorized State

A State with an NPDES permit program approved pursuant to section 402(b) of the Act and an approved State Pretreatment Program.

Baseline Monitoring Report (BMR) [paraphrased from 40 CFR §403.12(b)]

A report submitted by categorical industrial users (CIUs) within 180 days after the effective date of an applicable categorical standard, or at least 90 days prior to commencement of discharge for new sources, which contains specific facility information, including flow and pollutant concentration data. For existing sources, the report must also certify as to the compliance status of the facility with respect to the categorical standards.

Best Available Technology Economically Achievable (BAT)

A level of technology based on the best existing control and treatment measures that are economically achievable within the given industrial category or subcategory.

Best Management Practices (BMPs)

Schedules of activities, prohibitions of practices, maintenance procedures, and other management practices to prevent or reduce the pollution of waters of the U.S. BMPs also include treatment requirements, operating procedures and practices to control plant site runoff, spillage or leaks, sludge or waste disposal, or drainage from raw material storage.

Best Practicable Control Technology Currently Available (BPT)

A level of technology represented by the average of the best existing wastewater treatment performance levels within an industrial category or subcategory.

Best Professional Judgment (BPJ)

The method used by a permit writer to develop technology-based limitations on a case-by-case basis using all reasonably available and relevant data.

Blowdown

The discharge of water with high concentrations of accumulated solids from boilers to prevent plugging of the boiler tubes and/or steam lines. In cooling towers, blowdown is discharged to reduce the concentration of dissolved salts in the recirculating cooling water.

Bypass [40 CFR §403.17(a)]

The intentional diversion of wastestreams from any portion of an Industrial User's treatment facility.

Categorical Industrial User (CIU)

An industrial user subject to National categorical pretreatment standards.



Categorical Pretreatment Standards [40 CFR § 403.6 and 40 CFR Parts 405-471]

Limitations on pollutant discharges to POTWs promulgated by the EPA in accordance with Section 307 of the Clean Water Act, that apply to specific process wastewater discharges of particular industrial categories.

Chain of Custody (COC)

A record of each person involved in the possession of a sample from the person who collects the sample to the person who analyzes the sample in the laboratory.

Chronic

A stimulus that lingers or continues for a relatively long period of time, often one-tenth of the life span or more. Chronic should be considered a relative term depending on the life span of an organism. The measurement of chronic effect can be reduced growth, reduced reproduction, etc., in addition to lethality.

Clean Water Act (CWA)

The common name for the Federal Water Pollution Control Act. Public law 92-500; 33 U.S.C. 1251 et seq.; legislation which provides statutory authority for both NPDES and Pretreatment Programs.

Code of Federal Regulations (CFR)

A codification of Federal rules published annually by the Office of the Federal Register National Archives and Records Administration. Title 40 of the CFR contains the regulations for *Protection of the Environment*.

Combined Sewer Overflow (CSO)

A discharge of untreated wastewater from a combined sewer system at a point prior to the headworks of a publicly owned treatment works. CSOs generally occur during wet weather (rainfall or snowfall). During periods of wet weather, these systems become overloaded, bypass treatment works, and discharge directly to receiving waters.

Combined Wastestream Formula (CWF) [paraphrased from 40 CFR §403.6(e)]

Procedure for calculating alternative discharge limits at industrial facilities where a regulated wastestream from a categorical industrial user is combined with other wastestreams prior to treatment.

Compliance Schedule

A schedule of remedial measures included in a permit or an enforcement order, including a sequence of interim requirements (for example, actions, operations, or milestone events) that lead to compliance with the CWA and regulations.

Composite Sample

Sample composed of two or more discrete samples. The aggregate sample will reflect the average water quality covering the compositing or sample period.

Concentration-based Limit

A limit based upon the relative strength of a pollutant in a wastestream, usually expressed in mg/l.

Continuous Discharge

A discharge that occurs without interruption during the operating hours of a facility, except for infrequent shutdowns for maintenance, process changes or similar activities.

Control Authority [paraphrased from 40 CFR § 403.12(a)]

A POTW with an approved pretreatment program or the approval authority in the absence of a POTW pretreatment program.

Conventional Pollutants

BOD, TSS, fecal coliform, oil and grease, and pH

Daily Maximum Limitations

The maximum allowable discharge of pollutants during a 24-hour period. Where daily maximum limitations are expressed in units of mass, the daily discharge is the total mass discharged over the course of the day. Where daily maximum limitations are expressed in terms of a concentration, the daily discharge is the arithmetic average measurement of the pollutant concentration derived from all measurements taken that day.

Detection Limit

The minimum concentration of an analyte (substance) that can be measured and reported with a 99% confidence that the analyte concentration is greater than zero as determined by the procedure set forth in 40 CFR Part 136, Appendix B.

Development Document

Detailed report of studies conducted by the U.S. EPA for the purpose of establishing effluent guidelines and categorical pretreatment standards.

Dilute Wastestream *[paraphrased from 40 CFR §403.6(e)(1)(i)]*

For purposes of the combined wastestream formula, the average daily flow (at least a 30-day average) from : (a) boiler blowdown streams, non-contact cooling streams, storm water streams, and demineralized backwash streams; provided, however, that where such streams contain a significant amount of a pollutant, and the combination of such streams, prior to treatment, with an industrial user's regulated process wastestream(s) will result in a substantial reduction of that pollutant, the Control Authority, upon application of the industrial user, may exercise its discretion to determine whether such stream(s) should be classified as diluted or unregulated. In its application to the Control Authority, the industrial user must provide engineering, production, sampling and analysis, and such other information so the control authority can make its determination; or (b) sanitary wastestreams where such streams are not regulated by a categorical pretreatment standard; or (c) from any process wastestreams which were, or could have been, entirely exempted from categorical pretreatment standards pursuant to paragraph 8 of the NRDC v. Costle Consent Decree (12 ERC 1833) for one more of the following reasons (see Appendix D of 40 CFR Part 403):

- a. the pollutants of concern are not detectable in the effluent from the industrial user (paragraph(8)(a)(iii));
- b. the pollutants of concern are present only in trace amounts and are neither causing nor likely to cause toxic effects (paragraph (8)(a)(iii));
- c. the pollutants of concern are present in amounts too small to be effectively deduced by technologies known to the Administrator (paragraph (8)(a)(iii)); or
- d. the wastestream contains only pollutants which are compatible with the POTW (paragraph (8)(b)(I)).

Effluent Limitations Guideline

Any effluent limitations guidelines issued by the EPA pursuant to Section 304(b) of the CWA. These regulations are published to adopt or revise a national standard prescribing restrictions on quantities, rates, and concentrations of chemical, physical, biological, and other constituents which are discharged from point sources, in specific industrial categories (e.g., metal finishing, metal molding and casting, etc.).

Enforcement Response Plan *[paraphrased from 40 CFR §403.8(f)(5)]*

Step-by-step enforcement procedures followed by Control Authority staff to identify, document, and respond to violations.

Existing Source

Any source of discharge, the construction or operation of which commenced prior to the publication by the EPA of proposed categorical pretreatment standards, which will be applicable to such source if the standard is thereafter promulgated in accordance with Section 307 of the Act.

Federal Water Pollution Control Act (FWPCA)

The title of Public law 92-500; 33 U.S.C. 1251 et seq., also known as the Clean Water Act (CWA), enacted October 18, 1972.

Flow Weighted Average Formula (FWA) *[paraphrased from 40 CFR §403.6(e)]*

A procedure used to calculate alternative limits where wastestreams regulated by a categorical pretreatment standard and nonregulated wastestreams combine after treatment but prior to the monitoring point.

Flow Proportional Composite Sample

Combination of individual samples proportional to the flow of the wastestream at the time of sampling.

Fundamentally Different Factors *[paraphrased from 40 CFR §403.13]*

Case-by-case variance from categorical pretreatment standards based on the factors considered by the EPA in developing the applicable category/subcategory being fundamentally different than factors relating to a specific industrial user.



General Prohibitions [40 CFR §403.5(a)(1)]

No user shall introduce into a POTW any pollutant(s) which cause pass through or interference.

Grab Sample

A sample which is taken from a wastestream on a one-time basis with no regard to the flow of the wastestream and without consideration of time. A single grab sample should be taken over a period of time not to exceed 15 minutes.

Indirect Discharge or Discharge [40 CFR §403.3(g)]

The introduction of pollutants into a POTW from any non-domestic source regulated under section 307(b), (c), or (d) of the Act.

Industrial User (IU) or User [40 CFR §403.3(h)]

A source of indirect discharge.

Industrial Waste Survey

The process of identifying and locating industrial users and characterizing their industrial discharge.

Inhibition Concentration

Estimate of the toxicant concentration that would cause a given percent reduction (e.g., IC25) in a nonlethal biological measurement of the test organisms, such as reproduction or growth.

Interference [paraphrased from 40 CFR §403.3(i)]

A discharge which, alone or in conjunction with a discharge or discharges from other sources, both: (1)inhibits or disrupts the POTW, its treatment processes or operations, or its sludge processes, use or disposal; and (2) therefore is a cause of a violation of any requirement of the POTW's NPDES permit (including an increase in the magnitude or duration of a violation) or of the prevention of sewage sludge use or disposal in compliance with ... [applicable] statutory provisions and regulations or permits issued there under (or more stringent State or local regulations)

Local Limits [paraphrased 40 CFR § 403.5(c)]

Specific discharge limits developed and enforced by POTWs upon industrial or commercial facilities to implement the general and specific discharge prohibitions listed in 40 CFR §§403.5(a)(1) and (b).

Monthly Average

The arithmetic average value of all samples taken in a calendar month for an individual pollutant parameter. The monthly average may be the average of all grab samples taken in a given calendar month, or the average of all composite samples taken in a given calendar month.

National Pollutant Discharge Elimination System (NPDES)

The national program for issuing, modifying, revoking and reissuing, terminating, monitoring and enforcing discharge permits from point sources to waters of the United States, and imposing and enforcing pretreatment requirements, under sections 307, 402, 318, and 405 of the CWA.

National Pretreatment Standard or Pretreatment Standard or Standard

[40 CFR §403.3(j)] Any regulation containing pollutant discharge limits promulgated by the EPA in accordance with section 307(b) and (c) of the Act, which applies to Industrial Users. This term includes prohibitive discharge limits established pursuant to §403.5.

New Source [40 CFR §403.3(k)]

Any building, structure, facility or installation from which there is or may be a discharge of pollutants, the construction of which commenced after the publication of proposed Pretreatment Standards under section 307(c) of the Act which will be applicable to such source if such standards are thereafter promulgated in accordance with that section *provided that*:

- (a) The building, structure, facility or installation is constructed at a site at which no other discharge source is located; or
- (b) The building, structure, facility or installation totally replaces the process or production equipment that causes the discharge of pollutants at an existing source; or
- (c) The production or wastewater generating processes of the building, structure, facility, or installation are substantially independent of an existing source at the same site. In determining whether these are substantially independent, factors such as the extent to which the new facility is integrated with the existing

plant, and the extent to which the new facility is engaged in the same general type of activity as the existing source, should be considered.

Construction on a site at which an existing source is located results in a modification rather than a new source if the construction does not create a new building, structure, facility, or installation meeting the criteria of paragraphs (k)(1)(ii), or (k)(1)(iii) of this section but otherwise alters, replaces, or adds to existing processor production equipment.

Construction of a new source, as defined under this paragraph has commenced if the owner or operator has:

(i) Begun, or caused to begin as part of a continuous onsite construction program:

(A) Any placement, assembly, or installation of facilities or equipment; or

(B) Significant site preparation work including clearing, excavation, or removal of existing buildings, structures, or facilities which is necessary for the placement, assembly, or installation of new source facilities or equipment, or

(C) Entered into a binding contractual obligation for the purchase of facilities or equipment which are intended to be used in its operation within a reasonable time. Options to purchase or contracts which can be terminated or modified without substantial loss, and contracts for feasibility, engineering, and design studies do not constitute a contractual obligation under this paragraph.

90-Day Final Compliance Report [40 CFR §403.12(d)]

A report submitted by categorical industrial users within 90 days following the date for final compliance with the standards. This report must contain flow measurement (of regulated process streams and other streams), measurement of pollutants, and a certification as to whether the categorical standards are being met.

Nonconventional Pollutants

Any pollutant that is neither a toxic pollutant nor a conventional pollutant (e.g., manganese, ammonia, etc.)

Non-Contact Cooling Water

Water used for cooling which does not come into direct contact with any raw material, intermediate product, waste product, or finished product. The only pollutant contributed from the discharge is heat.

Non-Regulated Wastestream

Unregulated and dilute wastestreams (not regulated by categorical standards).

Pass Through [40 CFR §403.3(n)]

A discharge which exits the POTW into waters of the United States in quantities or concentrations which, alone or in conjunction with a discharge or discharges from other sources, is a cause of a violation of any requirement of the POTW's NPDES permit (including an increase in the magnitude or duration of a violation).

Periodic Compliance Report [paraphrased from 40 CFR §403.12(e) & (h)]

A report on compliance status submitted by categorical industrial users and significant noncategorical industrial users to the control authority at least semiannually (once every six months).

Point Source [40 CFR 122.2]

Any discernible, confined, and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fixture, container, rolling stock concentrated animal feeding operation vessel, or other floating craft from which pollutants are or may be discharged.

Pollutant [40 CFR 122.2]

Dredged spoil, solid waste, incinerator residue, filter backwash, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials (except those regulated under the Atomic Energy Act of 1954, as amended (42 U.S.C. 2011 et seq.)), heat, wrecked or discarded equipment, rock, sand, cellar dirt, and industrial, municipal and agricultural waste discharged into water.



Pretreatment *[paraphrased from 40 CFR §403.3(q)]*

The reduction of the amount of pollutants, the elimination of pollutants, or the alteration of the nature of pollutant properties in wastewater prior to or in lieu of discharging or otherwise introducing such pollutants into a POTW.

Pretreatment Requirements *[40 CFR §403.3(r)]*

Any substantive or procedural requirement related to Pretreatment, other than a National Pretreatment Standard, imposed on an Industrial User.

Pretreatment Standards for Existing Sources (PSES)

Categorical Standards and requirements applicable to industrial sources that began construction prior to the publication of the proposed pretreatment standards for that industrial category. (see individual standards at 40 CFR Parts 405-471.)

Pretreatment Standards for New Sources (PSNS)

Categorical Standards and requirements applicable to industrial sources that began construction after the publication of the proposed pretreatment standards for that industrial category. (see individual standards at 40 CFR Parts 405-471.)

Priority Pollutant

Pollutant listed by the Administrator of the EPA under Clean Water Act section 307(a). The list of the current 126 Priority Pollutants can be found in 40 CFR Part 423 Appendix A.

Process Wastewater

Any water which, during manufacturing or processing, comes into contact with or results from the production or use of any raw material, intermediate product, finished product, byproduct, or waste product.

Production-Based Standards

A discharge standard expressed in terms of pollutant mass allowed in a discharge per unit of product manufactured.

Publicly Owned Treatment Works (POTW) *[40 CFR §403.3(o)]*

A treatment works as defined by section 212 of the Act, which is owned by a State or municipality (as defined by section 502(4) of the Act). This definition includes any devices or systems used in the storage, treatment, recycling, and reclamation of municipal sewage or industrial wastes of a liquid nature. It also includes sewers, pipes or other conveyances only if they convey wastewater to a POTW Treatment Plant.

The term also means the municipality as defined in section 502(4) of the Act, which has jurisdiction over the Indirect Discharges to and the discharges from such a treatment works.

Regulated Wastestream

For purposes of applying the combined wastestream formula, a wastestream from an industrial process that is regulated by a categorical standard.

Removal Credit *[paraphrased from 40 CFR §403.7]*

Variance from a pollutant limit specified in a categorical pretreatment standard to reflect removal by the POTW of said pollutant.

Representative Sample

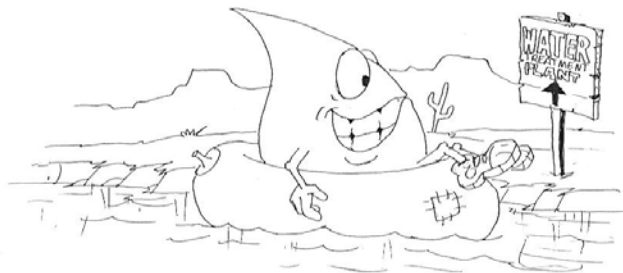
A sample from a wastestream that is as nearly identical as possible in composition to that in the larger volume of wastewater being discharged and typical of the discharge from the facility on a normal operating day.

Sanitary Sewer Overflow (SSO)

Untreated or partially treated sewage overflows from a sanitary sewer collection system.

Self-Monitoring

Sampling and analyses performed by a facility to ensure compliance with a permit or other regulatory requirements.



Sewer Use Ordinance (SUO)

A legal mechanism implemented by a local government entity which sets out, among others, requirements for the discharge of pollutants into a publicly owned treatment works.

Significant Industrial User (SIU) [paraphrased from 40 CFR §403.3(t)]

(1) All users subject to Categorical Pretreatment Standards under 40 CFR 403.6 and 40 CFR chapter I, subchapter N; and (2) Any other industrial user that: discharges an average of 25,000 gallons per day or more of process wastewater to the POTW (excluding sanitary, noncontact cooling and boiler blowdown wastewater); contributes a process wastestream which makes up 5 percent or more of the average dry weather hydraulic or organic capacity of the POTW treatment plant; or is designated as such by the Control Authority as defined in 40 CFR 403.12(a) on the basis that the industrial user has a reasonable potential for adversely affecting the POTW's operation or for violating any pretreatment standard or requirement (in accordance with 40 CFR 403.8(f)(6)).

Significant Noncompliance (SNC) [40 CFR §403.8(f)(2)(vii)]

Industrial user violations meeting one or more of the following criteria:

- 1) Chronic violations of wastewater discharge limits, defined here as those in which sixty-six percent or more of all of the measurements taken during a six month period exceed (by any magnitude) the daily maximum limit or the average limit for the same pollutant parameter;
- 2) Technical Review Criteria (TRC) violations, defined here as those in which thirty-three percent or more of all of the measurements for each pollutants parameter taken during a six-month period equal or exceed the product of the daily maximum limit or the average limit multiplied by the applicable TRC (TRC=1.4 for BOD, TSS, fats, oil, and grease, and 1.2 for all other pollutants except pH);
- 3) Any other violation of a pretreatment effluent limit (daily maximum or longer-term average) that the Control Authority determines has caused, alone or in combination with other dischargers, interference or pass through (including endangering the health of POTW personnel or the general public);
- 4) Any discharge of a pollutant that has caused imminent endangerment to human health, welfare or to the environment or has resulted in the POTW's exercise of its emergency authority under paragraph (f)(1)(vi)(B) of this section to halt or prevent such a discharge;
- 5) Failure to meet, within 90 days after the schedule date, a compliance schedule milestone contained in a local control mechanism or enforcement order for starting construction, completing construction, or attaining final compliance;
- 6) Failure to provide, within 30 days after the due date, required reports such as baseline monitoring reports, 90-day compliance reports, periodic self-monitoring reports, and reports on compliance with compliance schedules;
- 7) Failure to accurately report noncompliance;
- 8) Any other violation or group of violations which the Control Authority determines will adversely affect the operation or implementation of the local pretreatment program.

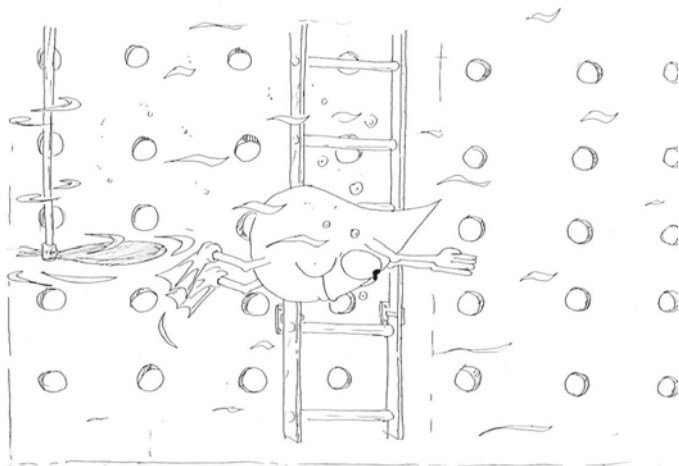
Slug Discharge [40 CFR §403.8(f)(2)(v)]

Any discharge of a non-routine, episodic nature, including but not limited to, an accidental spill or a noncustomary batch discharge.

Specific Prohibitions [40 CFR §403.5(b)]

The following pollutants shall not be introduced into a POTW:

- 1) Pollutants which create a fire or explosion hazard in the POTW, including but not limited to, wastestreams with a closed cup flashpoint of less than 140 degrees Fahrenheit or 60 degrees Centigrade using the test methods specified in 40 CFR Part 261.21;
- 2) Pollutants which will cause corrosive structural damage to the POTW, but in no case discharges with pH lower than 5.0, unless the works is specifically designed to accommodate such discharges;
- 3) Solid or viscous pollutants in amounts which will cause obstruction to the flow in the POTW resulting in interference;
- 4) Any pollutant, including oxygen-demanding



pollutants (BOD, etc.) Released in a discharge at a flow rate and/or concentration which will cause interference with the POTW;

5) Heat in amounts which will inhibit biological activity in the POTW resulting in interference, but in no case heat in such quantities that the temperature at the POTW treatment plant exceeds 40°C (104°F) unless the Approval Authority, upon request of the POTW, approves alternative temperature limits;

6) Petroleum oil, nonbiodegradable cutting oil, or products of mineral oil origin in amounts that will cause interference or pass through;

7) Pollutants which result in the presence of toxic gases, vapors, or fumes within the POTW in a quantity that may cause acute worker health and safety problems;

8) Any trucked or hauled pollutants, except at discharge points designated by the POTW.

Standard Industrial Classification (SIC)

A system developed by the U.S. Office of Management and Budget that is used to classify various types of business entities. Effective in 1998, the SIC scheme is replaced by the North American Industry Classification System (**NAICS**), although the EPA has not yet implemented this change.

Storm Water

Rain water, snowmelt, and surface runoff and drainage.

Time Proportional Composite Sample

A sample consisting of a series of aliquots collected from a representative point in the discharge stream at equal time intervals over the entire discharge period on the sampling day.

Toxic Pollutant

Any pollutant listed as toxic under section 307(a)(1) of the CWA, or in the case of sludge use or disposal practices, any pollutant identified in regulations implementing section 405(d) of the CWA.

Toxicity Reduction Evaluation

A site-specific study conducted in a stepwise process designed to identify the causative agent(s) of effluent toxicity, isolate the sources of toxicity, evaluate the effectiveness of toxicity control options, and then confirm the reduction in effluent toxicity.

Toxicity Test

A procedure to determine the toxicity of a chemical or an effluent using living organisms. A toxicity test measures the degree of effect on exposed test organisms of a specific chemical or effluent.

Toxicity Identification Evaluation

Set of procedures to identify the specific chemicals responsible for effluent toxicity.

Unregulated Wastestream

For purposes of applying the combined wastestream formula, a wastestream not regulated by a categorical standard nor considered a dilute wastestream.

Upset [paraphrased from 40 CFR §403.16(a)]

An exceptional incident in which there is unintentional and temporary noncompliance with categorical Pretreatment Standards because of factors beyond the reasonable control of the Industrial User. An Upset does not include noncompliance to the extent caused by operational error, improperly designed treatment facilities, inadequate treatment facilities, lack of preventative maintenance, or careless or improper operation.

Water Quality Criteria

Comprised of both numeric and narrative criteria. Numeric criteria are scientifically derived ambient concentrations developed by EPA or States for various pollutants of concern to protect human health and aquatic life. Narrative criteria are statements that describe the desired water quality goal.

Water Quality Standard

A statute or regulation that consists of the beneficial designated use or uses of a waterbody, the numeric and narrative water quality criteria that are necessary to protect the use or uses of that particular waterbody, and an antidegradation statement.



Clean Water Act Summary

33 U.S.C. s/s 1251 et seq. (1977)

The Clean Water Act is a 1977 amendment to the Federal Water Pollution Control Act of 1972, which set the basic structure for regulating discharges of pollutants to waters of the United States.

The law gave the EPA the authority to set effluent standards on an industry basis (technology-based) and continued the requirements to set water quality standards for all contaminants in surface waters. The CWA makes it unlawful for any person to discharge any pollutant from a point source into navigable waters unless a permit (**NPDES**) is obtained under the act.

The 1977 amendments focused on toxic pollutants. In 1987, the PCA was reauthorized and again focused on toxic substances, authorized citizen suit provisions, and funded sewage treatment plants (**POTW's**) under the Construction Grants Program.

The CWA made provisions for the delegation by the EPA of many permitting, administrative, and enforcement aspects of the law to state governments. In states with the authority to implement CWA programs, the EPA still retains oversight responsibilities.

In 1972, Congress enacted the first comprehensive national clean water legislation in response to growing public concern for serious and widespread water pollution. The Clean Water Act is the primary federal law that protects our nation's waters, including lakes, rivers, aquifers and coastal areas.

Lake Erie was dying. The Potomac River was clogged with blue-green algae blooms that were a nuisance and a threat to public health. Many of the nation's rivers were little more than open sewers and sewage frequently washed up on shore. Fish kills were a common sight. Wetlands were disappearing at a rapid rate.

Today, the quality of our waters has improved dramatically as a result of a cooperative effort by federal, state, tribal and local governments to implement the pollution control programs established in 1972 by the Clean Water Act.

The Clean Water Act's primary objective is to restore and maintain the integrity of the nation's waters. This objective translates into two fundamental national goals:

- eliminate the discharge of pollutants into the nation's waters, and
- achieve water quality levels that are fishable and swimmable.

The Clean Water Act focuses on improving the quality of the nation's waters. It provides a comprehensive framework of standards, technical tools and financial assistance to address the many causes of pollution and poor water quality. It includes municipal and industrial wastewater discharges, polluted runoff from urban and rural areas, and habitat destruction.



For example, the Clean Water Act requires major industries to meet performance standards to ensure pollution control; charges states and tribes with setting specific water quality criteria appropriate for their waters and developing pollution control programs to meet them; provides funding to states and communities to help them meet their clean water infrastructure needs; protects valuable wetlands and other aquatic habitats through a permitting process that ensures development and other activities are conducted in an environmentally sound manner.

After 25 years, the Act continues to provide a clear path for clean water and a solid foundation for an effective national water program.

In 1972:

Only a third of the nation's waters were safe for fishing and swimming. Wetlands losses were estimated at about 460,000 acres annually.

Agricultural runoff resulted in the erosion of 2.25 billion tons of soil and the deposit of large amounts of phosphorus and nitrogen into many waters. Sewage treatment plants served only 85 million people.

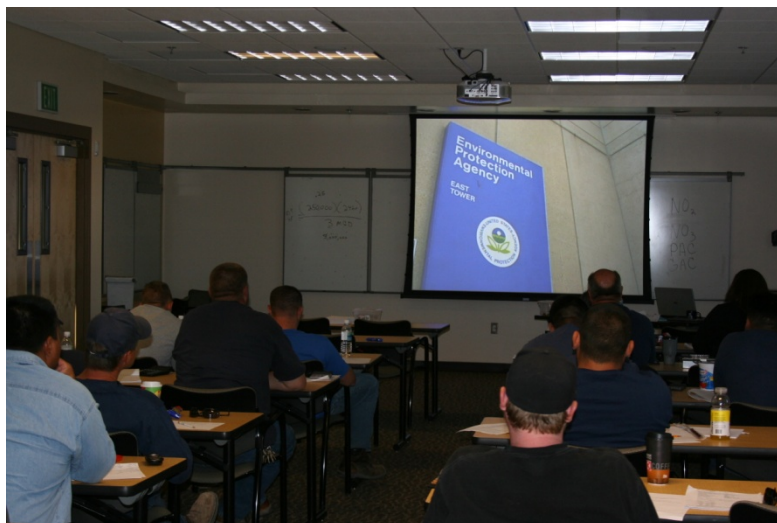
Today:

Two-thirds of the nation's waters are safe for fishing and swimming.

The rate of annual wetlands losses is estimated at about 70,000-90,000 acres according to recent studies. The amount of soil lost due to agricultural runoff has been cut by one billion tons annually, and phosphorus and nitrogen levels in water sources are down. Modern wastewater treatment facilities serve 173 million people.

The Future:

All Americans will enjoy clean water safe for fishing and swimming. We will achieve a net gain of wetlands by preventing additional losses and restoring hundreds of thousands of acres of wetlands. Soil erosion and runoff of phosphorus and nitrogen into watersheds will be minimized, helping to sustain the nation's farming economy and aquatic systems. The nation's waters will be free of effects of sewage discharges.



Chapter 1 What is a Pretreatment Program?

The term "**pretreatment**" refers to the requirement that non-domestic sources discharging wastewater to POTWs control their discharges, and meet limits established by the EPA, and/or your state or the local municipality (**Control Authority**) on the amount of pollutants allowed to be discharged. The control of the pollutants may necessitate treatment prior to discharge to the POTW (therefore the term "**pretreatment**").

Limits may often be met by the non-domestic source through pollution prevention techniques (product substitution, recycle and reuse of materials, more efficient production practices, improved environmental management systems, etc.), pretreatment of wastewater, or implementation of best management practices.

The National Pretreatment Program is a cooperative effort of federal, state, and local regulatory environmental agencies established to protect water quality. The program is designed to reduce the level of pollutants discharged by industry and other non-domestic wastewater sources into municipal sewer systems, and thereby, reduce the amount of pollutants released into the environment from these sources.

The national pretreatment program was established by Congress under authority of the Federal Water Pollution Control Act of 1972 (Pub. L. 92-500) as amended by the Clean Water Act of 1977 (Pub. L. 95-217). Implementation requirements of the pretreatment portions of these laws were first codified into 40 Code of Federal Regulations (**CFR**) Part 403 in 1978.

Objectives of the pretreatment program:

1. Protect publicly owned treatment works (**POTW**) from pollutants that may cause interference with sewage treatment plant operations.
2. Prevent introducing pollutants into a POTW that could cause pass through of untreated pollutants to receiving waters.
3. Manage pollutant discharges into a POTW to improve opportunities for reuse of POTW wastewater and residuals (sewage sludge).
4. Prevent introducing pollutants into a POTW that could cause worker health or safety concerns, or that could pose a potential endangerment to the public or to the environment.

POTWs

Publicly owned treatment works (**POTWs**) collect wastewater from homes, commercial buildings, and industrial facilities and transport it via a series of pipes, known as a collection system, to the treatment plant. Here, the POTW removes harmful organisms and other contaminants from the sewage so it can be discharged safely into the receiving stream. Generally, POTWs are designed to treat domestic sewage only.

However, POTWs also receive wastewater from industrial (non-domestic) users. The General Pretreatment Regulations establish responsibilities of Federal, State, and local government, industry and the public to implement Pretreatment Standards to control pollutants from the industrial users which may pass through or interfere with POTW treatment processes or which may contaminate sewage sludge.

National Pretreatment Program

The National Pretreatment Program identifies specific requirements that apply to all IUs, additional requirements that apply to all SIUs, and certain requirements that only apply to CIUs.

The objectives of the National Pretreatment Program are achieved by applying and enforcing three types of discharge standards:

- **prohibited discharge standards**
- **categorical Pretreatment standards**
- **local limits**

Prohibited Discharge Standards

Prohibited discharge standards are somewhat general, national standards are applicable to all industrial users to a POTW, regardless of whether or not the POTW has an approved pretreatment program or the industrial user has been issued a permit.

These standards are designed to protect against pass through and interference, protect the POTW collection system, and to promote worker safety and beneficial biosolids use. These standards are listed in 40 CFR 403.5

For Final Regulations pertaining to the Pretreatment Program, refer to 40 CFR Part 403 general pretreatment regulations (Located in the rear of this course).

Categorical Pretreatment Standards

Categorical Pretreatment Standards are limitations on pollutant discharges to publicly owned treatment works (POTWs), promulgated by the EPA in accordance with Section 307 of the Clean Water Act that apply to specific process wastewaters of particular industrial categories.

These are national, technology-based standards that apply regardless of whether or not the POTW has an approved pretreatment program or the industrial user has been issued a permit. Such industries are called Categorical Industrial Users. The standards applicable to industrial discharges to a POTW collection system are designated in the Effluent Guidelines & Limitations [Parts 405-471] by the terms "**Pretreatment Standards for Existing Sources**" (or "**PSES**") and "**Pretreatment Standards for New Sources**" (or "**PSNS**").

Note: The Effluent Guidelines & Limitations designated by the terms "**Best Practicable Control Technology Currently Available (BPT)**", "**Best Available Technology Economically Achievable (BAT)**", "**Best Conventional Pollutant Control Technology (BCT)**", and "**New Source Performance Standards (NSPS)**" apply to industries that discharge process wastewater to waters of the U.S. and should have a National Pollutant Discharge Elimination System (**NPDES**) Permit.

Regulations for all Effluent Guidelines and Standards are located at:
<http://www.epa.gov/docs/epacfr40/chapt-I.info/subch-N.htm>

Additional information on ongoing Categorical Standards Projects and recently published rules is located at: <http://www.epa.gov/ost/guide/>

Local Limits

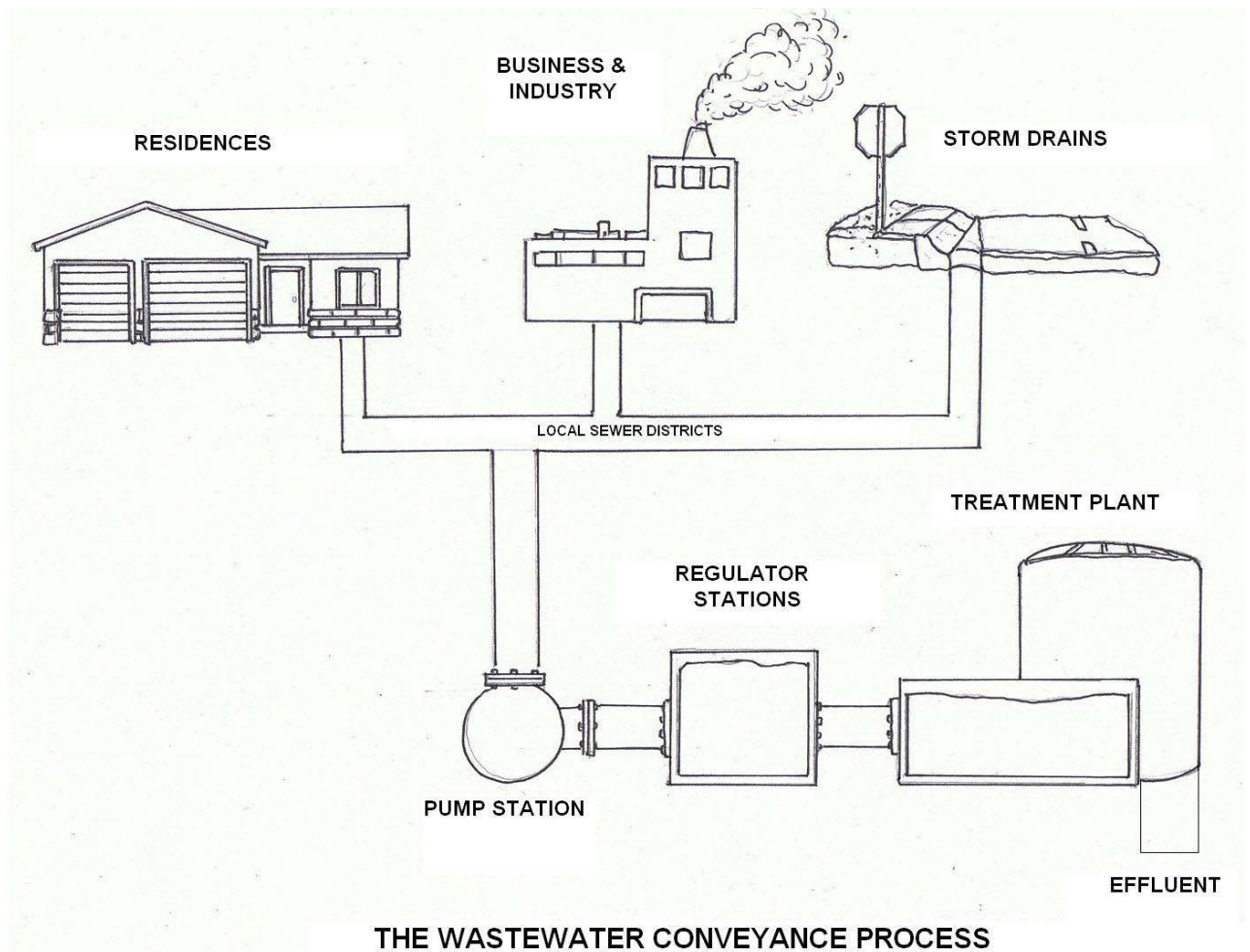
Local limits are developed to reflect specific needs and capabilities at individual POTWs and designed to protect the POTW receiving waters. Regulations at 40 CFR 403.8(f)(4) state that POTW Pretreatment Programs must develop local limits or demonstrate that they are unnecessary; 40 CFR 403.5(c) states that local limits are needed when pollutants are received that could result in pass through or interference at the POTW. Essentially, local limits translate the general prohibited discharge standards of 40 CFR 403.5 to site-specific needs.

Assistance on how to develop local limits may be found in the Guidance Manual for the Development and Implementation of Local Discharge Limitations Under the Pretreatment Program, December 1987 (EPA#833-B-87-202, ERIC#W107, NTIS#PB92-129188). Information related to ordering this publication from the Office of Wastewater Management is located at: <http://www.epa.gov/owm/inpub.htm>.

The EPA Supplemental Manual on the Development And Implementation of Local Discharge Limitations Under the Pretreatment Program: Residential and Commercial Toxic Pollutant Loadings and POTW Removal published May 1, 1991 provides information related to residential and commercial sources of toxic pollutants and estimated removal efficiencies of municipal treatment processes.



Two automatic wastewater samplers, one for Local Limits or compliance and the other for the wastewater plant operator to determine plant efficiency.



The Need for the Pretreatment Program

The average American uses roughly 100 to 200 gallons of water a day, with less than one percent of that water actually being consumed. The rest is used for activities such as washing, preparing food, watering lawns, heating and cooling, transporting wastes, and fire protection. The public is very conscious about the quality of water that comes out of their tap each day, quickly notifying authorities of changes in appearance, odor, and taste.

These same Americans, on average, discharge about the same amount of wastewater to local sewage treatment plants daily. This wastewater (commonly referred to as “**domestic sewage**”) receives much less attention than drinking water, likely the result of an “out of sight, out of mind” attitude.

Most people take it for granted that once down the drain, wastes will be handled appropriately. In fact, this attitude has carried over to industry as well, as can be seen by reading the labels of many household products. These labels often recommend that waste or excess product be disposed of down the drain. Other toxic or hazardous products are actually designed to be disposed of down the drain (e.g., drain clog remover).

Recall the phosphate detergent problems of the late 1960s and early 70s; large doses of phosphate, found in most detergents at the time, were passing through municipal treatment plants and overloading lakes, causing large algal blooms to form and subsequently reducing available light, food and oxygen for fish and other aquatic organisms. While great strides have been taken to address the phosphate problem, it is possible that other problematic pollutants are being dumped down the drain at the expense of human health and the environment.



Rotifer

Sewage Collection System

Publicly owned treatment works (**POTWs**) collect wastewater from homes, commercial buildings, and industrial facilities and transport it via a series of pipes, known as a collection system, to the treatment plant.

Collection systems may flow entirely by gravity, or may include lift stations that pump the wastewater via a force main to a higher elevation where the wastewater can then continue on via gravity. Ultimately, the collection system delivers this sewage to the treatment plant facility. Here, the POTW removes harmful organisms and other contaminants from the sewage so it can be discharged safely into the receiving stream.



New sewer manhole with sewer mains before final burial.

Without treatment, sewage creates bad odors, contaminates water supplies, and spreads disease. Today, more than 16,000 sewage treatment plants exist in the U.S. treating more than 32 billion gallons per day of wastewater.



Modern sewer vector or Camel. It is wise to make friends with the collection crews. The collection crews can greatly assist you in your enforcement efforts and can tell you lots of information, only if you develop a relationship with them.

POTWS

Generally, POTWs are designed to treat domestic sewage only. Simply defined, the typical POTW treatment process consists of primary and secondary treatment, along with some form of solids handling. Primary treatment is designed to remove large solids (e.g., rags and debris) and smaller inorganic grit. Typical primary treatment operations include screening and settling. Secondary treatment removes organic contaminants using microorganisms to consume biodegradable organics.



Odor control facility at a modern wastewater treatment plant--the picture on the right is of an enclosed “headworks” to help lower odor complaints.

Activated sludge, trickling filters, and rotating biological contactors are examples of common secondary treatment operations. Depending on effluent discharge requirements, POTWs may perform other “**advanced treatment**” operations such as nitrification (to convert ammonia and nitrite to the less toxic nitrate), denitrification (to convert nitrate to molecular nitrogen).



Aerated Wastewater

Conventional Pollutants *Figure 1*

- Biochemical Oxygen Demand (BOD)
- Total Suspended Solids (TSS)
- Fecal Coliform
- pH
- Oil and Grease (O&G)



A small wastewater treatment operator's lab.

Physical-Chemical Treatment

Physical-chemical treatment (to remove dissolved metals and organics), and disinfection (to kill any remaining pathogens). After treatment is complete, effluent is discharged to the receiving stream, typically a creek, river, lake, estuary or ocean. Some POTWs may apply treated effluent directly to golf courses, parkland, or croplands.

Both primary and secondary treatment processes generate waste solids, known as sewage sludge or biosolids. Sludges from the treatment process may be used productively (i.e., as fertilizer or soil conditioner), disposed of in a landfill or incinerated in a dedicated sewage sludge incinerator with the ash also disposed of in a landfill.

As described above, POTWs are designed to treat typical household wastes and biodegradable commercial and biodegradable industrial wastes. The Clean Water Act (**CWA**) and the EPA define the contaminants from these sources as conventional pollutants. Conventional pollutants are identified in Figure 1 above and include those specific pollutants that are expected to be present in domestic discharges to POTWs.

Commercial and industrial facilities may, however, discharge toxic pollutants that the treatment plant is neither designed for nor able to remove.

What is in Wastewater?

Wastewater is mostly water by weight. Other materials make up only a small portion of wastewater, but can be present in large enough quantities to endanger public health and the environment. Because practically anything that can be flushed down a toilet, drain, or sewer can be found in wastewater, even household sewage contains many potential pollutants. The wastewater components that should be of most concern to homeowners and communities are those that have the potential to cause disease or detrimental environmental effects.

Organisms

Many different types of organisms live in wastewater and some are essential contributors to treatment. A variety of bacteria, protozoa, and worms work to break down certain carbon-based (organic) pollutants in wastewater by consuming them. Through this process, organisms turn wastes into carbon dioxide, water, or new cell growth.

Bacteria and other microorganisms are particularly plentiful in wastewater and accomplish most of the treatment. Most wastewater treatment systems are designed to rely in large part on biological processes.

Pathogens

Many disease-causing viruses, parasites, and bacteria are also present in wastewater and enter from almost anywhere in the community. These pathogens often originate from people and animals that are infected with or are carriers of a disease. Graywater and blackwater from typical homes contain enough pathogens to pose a risk to public health. Other likely sources in communities include hospitals, schools, farms, and food processing plants.

Some illnesses from wastewater-related sources are relatively common. Gastroenteritis can result from a variety of pathogens in wastewater, and cases of illnesses caused by the parasitic protozoa *Giardia lamblia* and *Cryptosporidium* are not unusual in the U.S. Other important wastewater-related diseases include hepatitis A, typhoid, polio, cholera, and dysentery.

Outbreaks of these diseases can occur as a result of drinking water from wells polluted by wastewater, eating contaminated fish, or recreational activities in polluted waters. Some illnesses can be spread by animals and insects that come in contact with wastewater.

Even municipal drinking water sources are not completely immune to health risks from wastewater pathogens. Drinking water treatment efforts can become overwhelmed when water resources are heavily polluted by wastewater. For this reason, wastewater treatment is as important to public health as drinking water treatment.

Organic Matter

Organic materials are found everywhere in the environment. They are composed of the carbon-based chemicals that are the building blocks of most living things. Organic materials in wastewater originate from plants, animals, or synthetic organic compounds, and enter wastewater in human wastes, paper products, detergents, cosmetics, foods, and from agricultural, commercial, and industrial sources.

Organic compounds normally are some combination of carbon, hydrogen, oxygen, nitrogen, and other elements. Many organics are proteins, carbohydrates, or fats and are biodegradable, which means they can be consumed and broken down by organisms. However, even biodegradable materials can cause pollution. In fact, too much organic matter in wastewater can be devastating to receiving waters.

Large amounts of biodegradable materials are dangerous to lakes, streams, and oceans, because organisms use dissolved oxygen in the water to break down the wastes. This can reduce or deplete the supply of oxygen in the water needed by aquatic life, resulting in fish kills, odors, and overall degradation of water quality. The amount of oxygen organisms need to break down wastes in wastewater is referred to as the biochemical oxygen demand (BOD) and is one of the measurements used to assess overall wastewater strength.

Some organic compounds are more stable than others and cannot be quickly broken down by organisms, posing an additional challenge for treatment. This is true of many synthetic organic compounds developed for agriculture and industry.

In addition, certain synthetic organics are highly toxic. Pesticides and herbicides are toxic to humans, fish, and aquatic plants and often are disposed of improperly in drains or carried in stormwater. In receiving waters, they kill or contaminate fish, making them unfit to eat. They can also damage processes in treatment plants. Benzene and toluene are two toxic organic compounds found in some solvents, pesticides, and other products. New synthetic organic compounds are being developed all the time, which can complicate treatment efforts.

Oil and Grease

Fatty organic materials from animals, vegetables, and petroleum also are not quickly broken down by bacteria and can cause pollution in receiving environments. When large amounts of oils and greases are discharged to receiving waters from community systems, they increase BOD and they may float to the surface and harden, causing aesthetically displeasing conditions. They also can trap trash, plants, and other materials, causing foul odors, attracting flies, mosquitoes and other disease vectors. In some cases, too much oil and grease causes septic conditions in ponds and lakes by preventing oxygen from the atmosphere from reaching the water.

Onsite systems also can be harmed by too much oil and grease, which can clog onsite system drainfield pipes and soils, adding to the risk of system failure. Excessive grease also adds to the septic tank scum layer, requiring more frequent tank pumping. Both possibilities can result in significant costs to homeowners.

Petroleum-based waste oils used for motors and industry are considered hazardous waste and should be collected and disposed of separately from wastewater.

Inorganics

Inorganic minerals, metals, and compounds, such as sodium, potassium, calcium, magnesium, cadmium, copper, lead, nickel, and zinc are common in wastewater from both residential and nonresidential sources. They can originate from a variety of sources in the community including industrial and commercial sources, stormwater, inflow and infiltration from cracked pipes and leaky manhole covers. Most inorganic substances are relatively stable, and cannot be broken down easily by organisms in wastewater.

Large amounts of many inorganic substances can contaminate soil and water. Some are toxic to animals and humans and may accumulate in the environment. For this reason, extra treatment steps are often required to remove inorganic materials from industrial wastewater sources. For example, heavy metals which are discharged with many types of industrial wastewaters are difficult to remove by conventional treatment methods. Although acute poisonings from heavy metals in drinking water are rare in the U.S., potential long-term health effects from ingesting small amounts of some inorganic substances over an extended period of time are possible.

Nutrients

Wastewater often contains large amounts of the nutrients nitrogen and phosphorus in the form of nitrate and phosphate, which promote plant growth. Organisms only require small amounts of nutrients in biological treatment, so there is normally an excess available in treated wastewater. In severe cases, excessive nutrients in receiving waters cause algae and other plants to grow quickly depleting oxygen in the water. Deprived of oxygen, fish and other aquatic life die, emitting foul odors.

Nutrients from wastewater have also been linked to ocean "red tides" that poison fish and cause illness in humans. Nitrogen in drinking water may contribute to miscarriages in pregnant women and is the cause of a serious illness in infants called methemoglobinemia or "blue baby syndrome."

Solids

Solid materials in wastewater can consist of organic and/or inorganic materials and organisms. The solids must be significantly reduced by treatment or they can increase BOD when discharged to receiving waters and provide places for microorganisms to escape disinfection. They also can clog soil absorption fields in onsite systems. Listed are the characteristics of solids.

- * **Settleable solids**-Certain substances, such as sand, grit, and heavier organic and inorganic materials settle out from the rest of the wastewater stream during the preliminary stages of treatment. On the bottom of settling tanks and ponds, organic material makes up a biologically active layer of sludge that aids in treatment.

- * **Suspended solids**-Materials that resist settling may remain suspended in wastewater. Suspended solids in wastewater must be treated, or they will clog soil absorption systems or reduce the effectiveness of disinfection systems.

- * **Dissolved solids**-Small particles of certain wastewater materials can dissolve like salt in water. Some dissolved materials are consumed by microorganisms in wastewater, but others, such as heavy metals, are difficult to remove by conventional treatment. Excessive amounts of dissolved solids in wastewater can have adverse effects on the environment.

Gases

Certain gases in wastewater can cause odors, affect treatment, or are potentially dangerous. Methane gas, for example, is a byproduct of anaerobic biological treatment and is highly combustible. Special precautions need to be taken near septic tanks, manholes, treatment plants, and other areas where wastewater gases can collect.

The gases hydrogen sulfide and ammonia can be toxic and pose asphyxiation hazards. Ammonia as a dissolved gas in wastewater also is dangerous to fish. Both gases emit odors, which can be a serious nuisance.

Unless effectively contained or minimized by design and location, wastewater odors can affect the mental well-being and quality of life of residents. In some cases, odors can even lower property values and affect the local economy.

Dispose of Household Hazardous Wastes Safely

Many household products are potentially hazardous to people and the environment and never should be flushed down drains, toilets, or storm sewers. Treatment plant workers can be injured and wastewater systems can be damaged as a result of improper disposal of hazardous materials.

Other hazardous chemicals cannot be treated effectively by municipal wastewater systems and may reach local drinking water sources. When flushed into septic systems and other onsite systems, they can temporarily disrupt the biological processes in the tank and soil absorption field, allowing hazardous chemicals and untreated wastewater to reach groundwater.

Some examples of hazardous household materials include motor oil, transmission fluid, antifreeze, paint, paint thinner, varnish, polish, wax, solvents, pesticides, rat poison, oven cleaner, and battery fluid. Many of these materials can be recycled or safely disposed of at community recycling centers.

Other Important Wastewater Characteristics

In addition to the many substances found in wastewater, there are other characteristics system designers and operators use to evaluate wastewater. For example, the color, odor, and turbidity of wastewater give clues about the amount and type of pollutants present and treatment necessary. The following are some other important wastewater characteristics that can affect public health and the environment, as well as the design, cost, and effectiveness of treatment.

Temperature

The best temperatures for wastewater treatment probably range from 77 to 95 degrees Fahrenheit. In general, biological treatment activity accelerates in warm temperatures and slows in cool temperatures, but extreme hot or cold can stop treatment processes altogether. Therefore, some systems are less effective during cold weather and some may not be appropriate for very cold climates.

Wastewater temperature also affects receiving waters. Hot water, for example, which is a byproduct of many manufacturing processes, can be a pollutant. When discharged in large quantities, it can raise the temperature of receiving streams locally and disrupt the natural balance of aquatic life.

pH

The acidity or alkalinity of wastewater affects both treatment and the environment. Low pH indicates increasing acidity; while a high pH indicates increasing alkalinity (a pH of 7 is neutral). The pH of wastewater needs to remain between 6 and 9 to protect organisms. Acids and other substances that alter pH can inactivate treatment processes when they enter wastewater from industrial or commercial sources.

Flow

Whether a system serves a single home or an entire community, it must be able to handle fluctuations in the quantity and quality of wastewater it receives to ensure proper treatment is provided at all times. Systems that are inadequately designed or hydraulically overloaded may fail to provide treatment and allow the release of pollutants to the environment.

To design systems are as safe and as cost-effective as possible, engineers must estimate the average and maximum (peak) amount of flows generated by various sources. Because extreme fluctuations in flow can occur during different times of the day and on different days of the week, estimates are based on observations of the minimum and maximum amounts of water used on an hourly, daily, weekly, and seasonal basis. The possibility of instantaneous peak flow events that result from several or all water-using appliances or fixtures being used at once is also taken into account.

The number, type, and efficiency of all water-using fixtures and appliances at the source is factored into the estimate (for example, the number and amount of water normally used by faucets, toilets, and washing machines), as is the number of possible users or units that can affect the amount of water used (for example, the number of residents, bedrooms, customers, students, patients, seats, or meals served). According to studies, water use in many homes is lowest from about midnight to 5 a.m., averaging less than one gallon per person per hour, but then rises sharply in the morning around 6 a.m. to a little over 3 gallons per person per hour. During the day, water use drops off moderately and rises again in the early evening hours.

Weekly peak flows may occur in some homes on weekends, especially when all adults work during the week. In U.S. homes, average water use is approximately 45 gallons per person per day, but may range from 35 to 60 gallons or more.

Peak flows at stores and other businesses typically occur during business hours and during meal times at restaurants. Rental properties, resorts, and commercial establishments in tourist areas may have extreme flow variations seasonally.

Estimating flow volumes for centralized treatment systems is a complicated task, especially when designing a new treatment plant in a community where one has never existed previously.

Engineers must allow for additional flows during wet weather due to inflow and infiltration of extra water into sewers. Excess water can enter sewers through leaky manhole covers and cracked pipes and pipe joints, diluting wastewater, which affects its overall characteristics. This can increase flows to treatment plants sometimes by as much as three or four times the original design load.

The main focus of wastewater treatment plants is to reduce the BOD and COD in the effluent discharged to natural waters, meeting state and federal discharge criteria. Wastewater treatment plants are designed to function as "microbiology farms," where bacteria and other microorganisms are fed oxygen and organic waste.

Treatment of wastewater usually involves biological processes such as the activated sludge system in the secondary stage after preliminary screening to remove coarse particles and primary sedimentation that settles out suspended solids.

These secondary treatment steps are generally considered environmental biotechnologies that harness natural self-purification processes contained in bioreactors for the biodegradation of organic matter and bioconversion of soluble nutrients in the wastewater.

Application Specific Microbiology

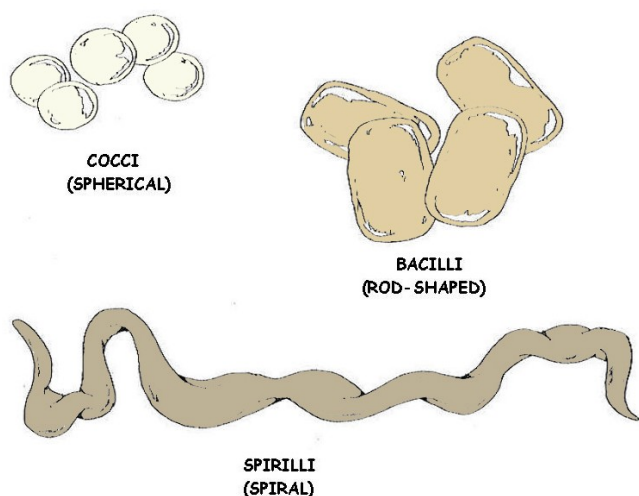
Each wastewater stream is unique, and so too are the community of microorganisms that process it. This "application-specific microbiology" is the preferred methodology in wastewater treatment affecting the efficiency of biological nutrient removal. The right laboratory prepared bugs are more efficient in organics removal if they have the right growth environment. This efficiency is multiplied if microorganisms are allowed to grow as a layer of biofilm on specifically designed support media. In this way, optimized biological processing of a waste stream can occur. To reduce the start-up phase for growing a mature biofilm one can also purchase "application-specific bacterial cultures" from appropriate microbiology vendors.

Bacteria

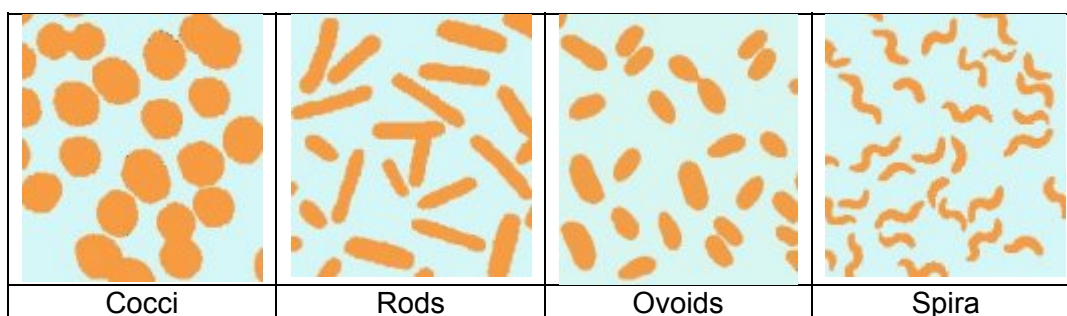
Bacteria are one of the most ancient of living things and some scientists believe they have been on this planet for nearly 4,000 million years. During this time they have acquired lots of fascinating and different ways of living. They also come in a variety of shapes.

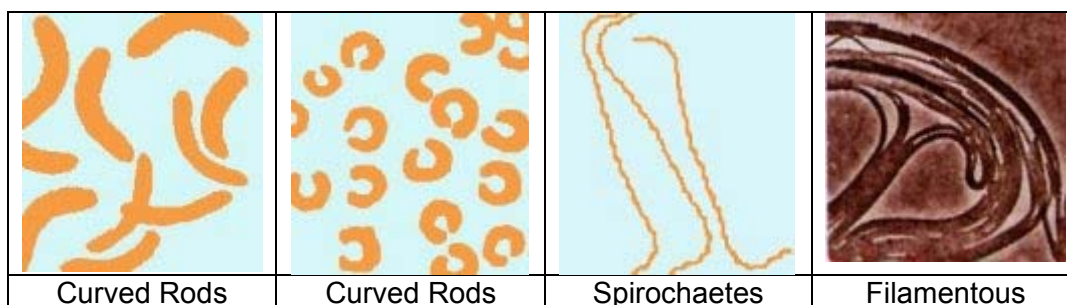
The simplest shape is a round sphere or ball. Bacteria formed like this are called cocci (singular coccus). The next simplest shape is cylindrical. Cylindrical bacteria are called rods (singular rod).

Some bacteria are basically rods but instead of being straight they are twisted or bent or curved, sometimes in a spiral. These bacteria are called spirilla (singular spirillum). Spirochaetes are tightly coiled up bacteria.



BACTERIA TYPES





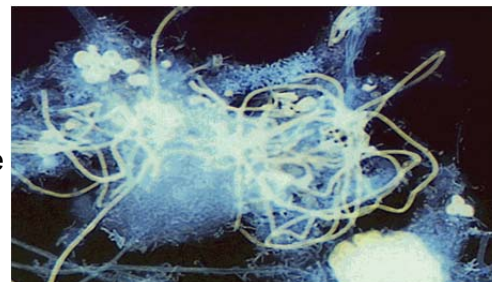
Bacteria are friendly creatures; you never find one bacteria on its own. They tend to live together in clumps, chains or planes. When they live in chains, one after the other, they are called filamentous bacteria that often have long thin cells. When they tend to collect in a plane or a thin layer over the surface of an object they are called a biofilm. Many bacteria exist as a biofilm and the study of biofilms is very important. Biofilm bacteria secrete sticky substances that form a sort of gel in which they live. The plaque on your teeth that causes tooth decay is a biofilm.



Filamentous Bacteria

Filamentous Bacteria are a type of bacteria that can be found in a wastewater treatment system. They function similar to floc forming bacteria in that they degrade BOD quite well. In small amounts, they are quite good to a biomass.

They can add stability and a backbone to the floc structure that keeps the floc from breaking up or shearing due to turbulence from pumps, aeration or transfer of the water. In large amounts they can cause many problems. Filaments are bacteria and fungi that grow in long thread-like strands or colonies.



Site Specific Bacteria

Aeration and biofilm building are the key operational parameters that contribute to the efficient degradation of organic matter (BOD/COD removal). Over time the application-specific bacteria become site specific as the biofilm develops and matures and is even more efficient in treating that site-specific waste stream.

Facultative Bacteria

Most of the bacteria absorbing the organic material in a wastewater treatment system are facultative in nature. This means they are adaptable to survive and multiply in either anaerobic or aerobic conditions. The nature of individual bacteria is dependent upon the environment in which they live. Usually, facultative bacteria will be anaerobic unless there is some type of mechanical or biochemical process used to add oxygen to the wastewater. When bacteria are in the process of being transferred from one environment to another, the metamorphosis from anaerobic to aerobic state (and vice versa) takes place within a couple of hours.

Anaerobic Bacteria

Anaerobic bacteria live and reproduce in the absence of free oxygen. They utilize compounds such as sulfates and nitrates for energy and their metabolism is substantially reduced. In order to remove a given amount of organic material in an anaerobic treatment system, the organic material must be exposed to a significantly higher quantity of bacteria and/or detained for a much longer period of time. A typical use for anaerobic bacteria would be in a septic tank. The slower metabolism of the anaerobic bacteria dictates the wastewater be held several days in order to achieve even a nominal 50% reduction in organic material. That is why septic tanks are always followed by some type of effluent treatment and disposal process. The advantage of using the anaerobic process is that electromechanical equipment is not required. Anaerobic bacteria release hydrogen sulfide as well as methane gas, both of which can create hazardous conditions. Even as the anaerobic action begins in the collection lines of a sewer system, deadly hydrogen sulfide or explosive methane gas can accumulate and be life threatening.

Aerobic Bacteria

Aerobic bacteria live and multiply in the presence of free oxygen. Facultative bacteria always achieve an aerobic state when oxygen is present. While the name "aerobic" implies breathing air, dissolved oxygen is the primary source of energy for aerobic bacteria. The metabolism of aerobes is much higher than for anaerobes. This increase means that 90% fewer organisms are needed compared to the anaerobic process, or that treatment is accomplished in 90% less time. This provides a number of advantages including a higher percentage of organic removal. The by-products of aerobic bacteria are carbon dioxide and water. Aerobic bacteria live in colonial structures called floc and are kept in suspension by the mechanical action used to introduce oxygen into the wastewater. This mechanical action exposes the floc to the organic material while treatment takes place. Following digestion, a gravity clarifier separates and settles out the floc. Because of the mechanical nature of the aerobic digestion process, maintenance and operator oversight are required.

Activated Sludge

Aerobic floc in a healthy state are referred to as activated sludge. While aerobic floc has a metabolic rate approximately ten times higher than anaerobic sludge, it can be increased even further by exposing the bacteria to an abundance of oxygen. Compared to a septic tank, which takes several days to reduce the organic material, an activated sludge tank can reduce the same amount of organic material in approximately 4-6 hours. This allows a much higher degree of overall process efficiency. In most cases treatment efficiencies and removal levels are so much improved, additional downstream treatment components are dramatically reduced or totally eliminated.

Filamentous Organisms

The majority of filamentous organisms are bacteria, although some of them are classified as algae, fungi or other life forms. There are a number of types of filamentous bacteria which proliferate in the activated sludge process. Filamentous organisms perform several different roles in the process, some of which are beneficial and some of which are detrimental. When filamentous organisms are in low concentrations in the process, they serve to strengthen the floc particles. This effect reduces the amount of shearing in the mechanical action of the aeration tank and allows the floc particles to increase in size.

Larger floc particles are more readily settled in a clarifier. Larger floc particles settling in the clarifier also tend to accumulate smaller particulates (surface adsorption) as they settle, producing an even higher quality effluent.

Conversely, if the filamentous organisms reach too high a concentration, they can extend dramatically from the floc particles and tie one floc particle to another (interfloc bridging) or even form a filamentous mat of extra-large size. Due to the increased surface area without a corresponding increase in mass, the activated sludge will not settle well. This results in less solids separation and may cause a washout of solid material from the system. In addition, air bubbles can become trapped in the mat and cause it to float, resulting in a floating scum mat. Due to the high surface area of the filamentous bacteria, once they reach an excess concentration, they can absorb a higher percentage of the organic material and inhibit the growth of more desirable organisms.

Protozoans and Metazoans

In a wastewater treatment system, the next higher life form above bacteria is protozoans. These single-celled animals perform three significant roles in the activated sludge process. These include floc formation, cropping of bacteria and the removal of suspended material. Protozoans are also indicators of biomass health and effluent quality. Because protozoans are much larger in size than individual bacteria, identification and characterization is readily performed. Metazoans are very similar to protozoans except they are usually multi-celled animals. Macroinvertebrates such as nematodes and rotifers, are typically found only in a well-developed biomass. The presence of protozoans and metazoans and the relative abundance of certain species can be a predictor of operational changes within a treatment plant. In this way, an operator is able to make adjustments and minimize negative operational effects simply by observing changes in the protozoan and metazoan population.

Dispersed Growth

Dispersed growth is material suspended within the activated sludge process that has not been adsorbed into the floc particles. This material consists of very small quantities of colloidal (too small to settle out) bacteria as well as organic and inorganic particulate material. While a small amount of dispersed growth in between the floc particles is normal, excessive amounts can be carried through a secondary clarifier. When discharged from the treatment plant, dispersed growth results in higher effluent solids.

Other Wastewater Treatment Components

Biochemical Oxygen Demand

Biochemical Oxygen Demand (**BOD or BOD₅**) is an indirect measure of biodegradable organic compounds in water, and is determined by measuring the dissolved oxygen decrease in a controlled water sample over a five-day period.

During this five-day period, **aerobic** (oxygen-consuming) bacteria decompose organic matter in the sample and consume dissolved oxygen in proportion to the amount of organic material that is present. In general, a high BOD reflects high concentrations of substances that can be biologically degraded, thereby consuming oxygen and potentially resulting in low dissolved oxygen in the receiving water.

The BOD test was developed for samples dominated by oxygen-demanding pollutants like sewage. While its merit as a pollution parameter continues to be debated, BOD has the advantage of a long period of record.

Nutrients

Nutrients are chemical elements or compounds essential for plant and animal growth. Nutrient parameters include ammonia, organic nitrogen, Kjeldahl nitrogen, nitrate nitrogen (for water only) and total phosphorus. High amounts of nutrients have been associated with eutrophication, or over fertilization of a water body, while low levels of nutrients can reduce plant growth and (for example) starve higher level organisms that consume phytoplankton.

Organic Carbon

Most organic carbon in water occurs as partly degraded plant and animal materials, some of which are resistant to microbial degradation. Organic carbon is important in the estuarine food web and is incorporated into the ecosystem by photosynthesis of green plants, then consumed as carbohydrates and other organic compounds by higher animals. In another process, formerly living tissue containing carbon is decomposed as detritus by bacteria and other microbes.

Total organic carbon (TOC)

TOC bears a direct relationship with biological and chemical oxygen demand. High levels of TOC can result from human sources, high oxygen demand being the main concern.

Priority Pollutants

Priority Pollutants refer to a list of 126 specific pollutants that includes heavy metals and specific organic chemicals. The priority pollutants are a subset of “**toxic pollutants**” as defined in the Clean Water Act.

These 126 pollutants were assigned a high priority for development of water quality criteria and effluent limitation guidelines because they are frequently found in wastewater. Many of the heavy metals, pesticides, and other chemicals listed on the following page are on the priority pollutant list.

Heavy Metals (Total and Dissolved)

Heavy metals are elements from a variety of natural and human sources. Some key metals of concern and their primary sources are listed below:

- **Arsenic** from fossil fuel combustion and industrial discharges;
- **Cadmium** from corrosion of alloys and plated surfaces, electroplating wastes, and industrial discharges;
- **Chromium** from corrosion of alloys and plated surfaces, electroplating wastes, exterior paints and stains, and industrial discharges;
- **Copper** from corrosion of copper plumbing, anti-fouling paints, and electroplating wastes;
- **Lead** from leaded gasoline, batteries, exterior paints and stains;
- **Mercury** from natural erosion and industrial discharges; and
- **Zinc** from tires, galvanized metal, and exterior paints and stains.

Discharge to POTW

As noted above, POTWs are not designed to treat toxics in industrial waste. As such, these discharges, from both industrial and commercial sources, can cause serious problems. The undesirable outcome of these discharges can be prevented using treatment techniques or management practices to reduce or eliminate the discharge of these contaminants. The act of treating wastewater prior to discharge to a POTW is commonly referred to as “**pretreatment**.” The National Pretreatment Program, published in **Title 40 Code of Federal Regulations (CFR) Part 403**, provides the regulatory basis to require non-domestic dischargers to comply with pretreatment standards (effluent limitations) to ensure that the goals of the CWA are attained.

As noted in 40CFR §403.2, the objectives of the National Pretreatment Program are to:

- a.** Prevent the introduction of pollutants into POTWs which will interfere with the operation of a POTW, including interference with its use or disposal of municipal sludge;
- b.** Prevent the introduction of pollutants into POTWs which will pass through the treatment works or otherwise be incompatible with such works; and
- c.** Improve opportunities to recycle and reclaim municipal and industrial wastewaters and sludges.

The two key terms used in the EPA’s objectives for the National Pretreatment Program, “**interference**” and “**pass through**,” are defined below.

Definitions

Interference - a discharge which, alone or in conjunction with a discharge or discharges from other sources, both inhibits or disrupts the POTW, its treatment processes or operations, or its sludge processes, use or disposal, and- therefore is a cause of a violation of any NPDES permit requirement or of the prevention of sewage sludge use or disposal in compliance with any applicable requirements.

Pass Through - a discharge which exits the POTW into waters of the U.S. in quantities or concentrations which, alone or in conjunction with a discharge or discharges from other sources, is a cause of a violation of any NPDES permit requirement.

As outlined in the EPA’s objectives, toxic pollutants may pass through the treatment plant into the receiving stream, posing serious threats to aquatic life, to human recreation, and to consumption of fish and shellfish from these waters. Pass through can make waters unswimmable or unfishable in direct contrast to the goals of the CWA. Or, these discharges can interfere with the biological activity of the treatment plant causing sewage to pass through the treatment plant untreated or inadequately treated.

Problems Associated With Toxic Discharges *Figure 3*

Air pollution can occur from volatilization of toxic chemicals in the POTW collection system or treatment plant, or through incineration of sewage sludge.

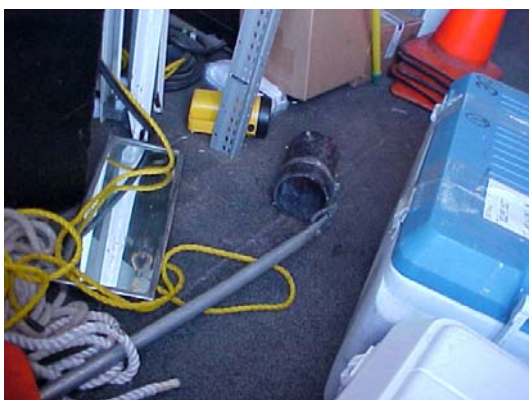
Corrosion of collection system and treatment plant from acidic discharges or discharges containing elevated levels of sulfate (forming toxic and corrosive hydrogen sulfide).

Groundwater pollution can occur from leaks in the collection system or pollutants from contaminated sewage sludge.

Toxic Emissions

Even where the POTW has the capability to remove these toxics, the pollutants may end up in the sewage sludge, thereby limiting sludge disposal options or escalating the cost of disposal. Incinerated contaminated sludge may release toxic emissions into the atmosphere. Toxic metals removed in primary treatment, while itself not an inhibitory process, can impact sludge digestion, a process that utilizes bacteria to stabilize sludge solids.

For example, chromium can inhibit reproduction of aerobic digestion microorganisms, thereby disrupting sludge treatment and producing sludges that must be disposed of with special treatment. Uncontaminated sludge, on the other hand, can be used as fertilizer or soil conditioner, thereby improving the productivity of our land. Many municipalities apply sewage sludge to pastureland or parkland that they could not do if the sludge were contaminated.



Tools of the Trade... Above photos, the Refrigerated Automatic Sampler will have a Data programmer which will allow you to set the time to collect the sample or samples. This machine can also measure the amount of the sample.

These can also be used for the collection of composite samples. Sometimes you will see a pH probe with real-time reads sent to the Operator's Command Center. A common site on most wastewater plants and SIUs.

One big disappointment, expect sampler failures. Dead batteries, wrong sample times and over and under filling the sampler is common.

VOCs

Volatile organics discharged to sewers can accumulate in the headspace of sewers, increasing the likelihood of explosions that can cause significant damage. Probably the most well-known impact from industrial discharges to POTWs in the U.S. is the explosion in Louisville, KY that occurred in 1981 as the result of excessive discharges of hexane into the collection system, eventually igniting and destroying more than 3 miles of sewers and causing \$20 million in damage. Discharge limitations and management practices to control slug discharges have significantly reduced the likelihood of future catastrophes such as the explosion in Louisville.

Discharges of toxic organics can also result in the release of poisonous gas. This occurs most often when acidic wastes react with other wastes in the discharge. For example, cyanide and acid, both present in many electroplating operations, react to form highly toxic hydrogen cyanide gas. Similarly, sulfides from leather tanning can combine with acid to form hydrogen sulfide, another toxic gas. These can be highly dangerous to POTW collection system operators exposed to such conditions in the performance of their duties.

Other problems associated with toxic discharges were summarized in Figure 3 and further document the urgency of keeping toxics out of collection systems and POTWs.

The National Pretreatment Program is charged with controlling the 129 Priority Pollutants from industries that discharge into sewer systems as described in the CWA (see Figure 4).

These pollutants fall into two categories; metals and organics:

- Metals, including lead, mercury, chromium, and cadmium that cannot be destroyed or broken down through treatment or environmental degradation. Toxic metals can cause different human health problems such as lead poisoning and cancer. Additionally, consumption of contaminated seafood and agricultural food crops has resulted in exposures exceeding recommended safe levels.
- Toxic organics, including solvents, pesticides, dioxins, and polychlorinated biphenyls (**PCBs**) can be cancer-causing and lead to other serious ailments, such as kidney and liver damage, anemia, and heart failure. In 1996, the EPA's Office of Science and Technology (**OST**) identified 2,193 water bodies with fish and wildlife advisories, up more than 25 percent from 1995.

Reductions in pollutants can ensure that industrial development vital to the economic well-being of a community is compatible with a healthy environment.

Many POTWs are responsible for ensuring that industrial and commercial facilities do not cause problems resulting from their discharges. In 1991, the EPA estimated that 190 to 204 million pounds of metals and 30 to 108 million pounds of organics were removed each year as a result of pretreatment program requirements.

This is substantiated by many POTWs that report significant reductions in the loadings of toxics to their treatment plants that is directly attributable to implementation of the National Pretreatment Program.

Priority Pollutants

001 Acenaphthene
002 Acrolein
003 Acrylonitrile
004 Benzene
005 Benzidine
006 Carbon tetrachloride
007 Chlorobenzene
008 1,2,4-trichlorobenzene
009 Hexachlorobenzene
010 1,2-dichloroethane
011 1,1,1-trichloroethane
012 Hexachloroethane
013 1,1-dichloroethane
014 1,1,2-trichloroethane
015 1,1,2,2-tetrachloroethane
016 Chloroethane
018 Bis(2-chloroethyl) ether
019 2-chloroethyl vinyl ethers
020 2-chloronaphthalene
021 2,4,6-trichlorophenol
022 Parachlorometa cresol
023 Chloroform
024 2-chlorophenol
025 1,2-dichlorobenzene
026 1,3-dichlorobenzene
027 1,4-dichlorobenzene
028 3,3-dichlorobenzidine
029 1,1-dichloroethylene
030 1,2-trans-dichloroethylene
031 2,4-dichlorophenol
032 1,2-dichloropropane
033 1,2-dichloropropylene
034 2,4-dimethylphenol
035 2,4-dinitrotoluene
036 2,6-dinitrotoluene
037 1,2-diphenylhydrazine
038 Ethylbenzene
039 Fluoranthene
040 4-chlorophenyl phenyl ether
041 4-bromophenyl phenyl ether
042 Bis(2-chloroisopropyl) ether

Figure 4

043 Bis(2-chloroethoxy) methane
044 Methylene chloride
045 Methyl chloride
046 Methyl bromide
047 Bromoform
048 Dichlorobromomethane
051 Chlorodibromomethane
052 Hexachlorobutadiene
053 Hexachlorocyclopentadiene
054 Isophorone
055 Naphthalene
056 Nitrobenzene
057 2-nitrophenol
058 4-nitrophenol
059 2,4-dinitrophenol
060 4,6-dinitro-o-cresol
061 N-nitrosodimethylamine
062 N-nitrosodiphenylamine
063 N-nitrosodi-n-propylamine
064 Pentachlorophenol
065 Phenol
066 Bis(2-ethylhexyl) phthalate
067 Butyl benzyl phthalate
068 Di-N-Butyl Phthalate
069 Di-n-octyl phthalate
070 Diethyl Phthalate
071 Dimethyl phthalate
072 benzo(a) anthracene
073 Benzo(a)pyrene
074 Benzo(b) fluoranthene
075 Benzo(b) fluoranthene
076 Chrysene
077 Acenaphthylene
078 Anthracene
079 Benzo(ghi) perylene
080 Fluorene
081 Phenanthrene
082 Dibenzo(,h) anthracene
083 Indeno (1,2,3-cd) pyrene
084 Pyrene
085 Tetrachloroethylene
086 Toluene
087 Trichloroethylene
088 Vinyl chloride
089 Aldrin
090 Dieldrin
091 Chlordane
092 4,4-DDT
093 4,4-DDE
094 4,4-DDD
095 Alpha-endosulfan
096 Beta-endosulfan
097 Endosulfan sulfate
098 Endrin
099 Endrin aldehyde
100 Heptachlor
101 Heptachlor epoxide
102 Alpha-BHC
103 Beta-BHC
104 Gamma-BHC
105 Delta-BHC
106 PCB-1242
107 PCB-1254
108 PCB-1221
109 PCB-1232
110 PCB-1248
111 PCB-1260
112 PCB-1016
113 Toxaphene
114 Antimony
115 Arsenic
116 Asbestos
117 Beryllium
118 Cadmium
119 Chromium
120 Copper
121 Cyanide, Total
122 Lead
123 Mercury
124 Nickel
125 Selenium
126 Silver
127 Thallium
128 Zinc
129 2,3,7,8-TCDD

Section 101 of the Clean Water Act (CWA)

To restore and maintain the chemical, physical, and biological integrity of the Nation's waters:

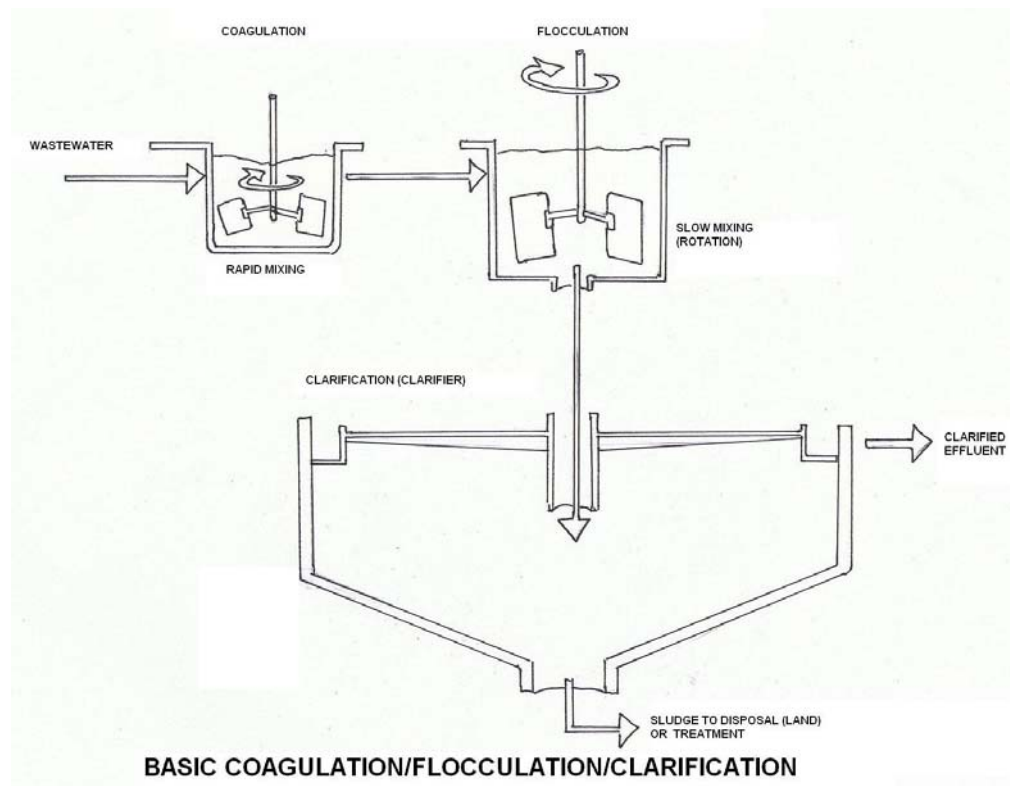
- (1) it is the national goal that the discharge of pollutants into the navigable waters be eliminated by 1985;
- (2) it is the national goal that wherever attainable, an interim goal of water quality which provides for the protection and propagation of fish, shellfish, and wildlife and provides for recreation in and on the water be achieved by July 1, 1983;
- (3) it is the national policy that the discharge of toxic pollutants in toxic amounts be prohibited;
- (4) it is the national policy that Federal financial assistance be provided to construct publicly owned waste treatment works;
- (5) it is the national policy that Area wide waste treatment management planning processes be developed and implemented to assure adequate control of sources of pollutants in each State;
- (6) it is the national policy that a major research and demonstration effort be made to develop technology necessary to eliminate the discharge of pollutants into the navigable waters, waters of the contiguous zone, and the oceans; and
- (7) it is the national policy that programs for the control of nonpoint sources of pollution be developed and implemented in an expeditious manner so as to enable the goals of this Chapter to be met through the control of both point and nonpoint sources of pollution.



Treated wastewater outfall.



Covered wastewater basins to help prevent or control odors.



Chapter 2

Overview of the National Pretreatment Program

The Clean Water Act

On October 18, 1972, the 92nd Congress of the United States passed the Federal Water Pollution Control Act Amendments of 1972, declaring the restoration and maintenance of the chemical, physical, and biological integrity of the Nation's water as a National Objective. While procedures for implementing this act (more commonly referred to as the Clean Water Act (**CWA**)) have been re-evaluated and modified over time, the 1972 objective has remained unchanged in its 31 year history.

The 1972 Amendments to the CWA established a water quality regulatory approach along with the EPA-promulgated industry-specific technology-based effluent limitations. The National Pollutant Discharge Elimination System (**NPDES**) permit program was established under the CWA to control the discharge of pollutants from point sources and served as a vehicle to implement the industrial technology-based standards. To implement pretreatment requirements, the EPA promulgated 40 CFR Part 128 in late 1973, establishing general prohibitions against treatment plant interference and pass through and pretreatment standards for the discharge of incompatible pollutants from specific industrial categories.

In 1975, several environmental groups filed suit against the EPA, challenging it's criteria for identifying toxic pollutants, the EPA's failure to promulgate effluent standards, and the EPA's failure to promulgate pretreatment standards for numerous industrial categories.

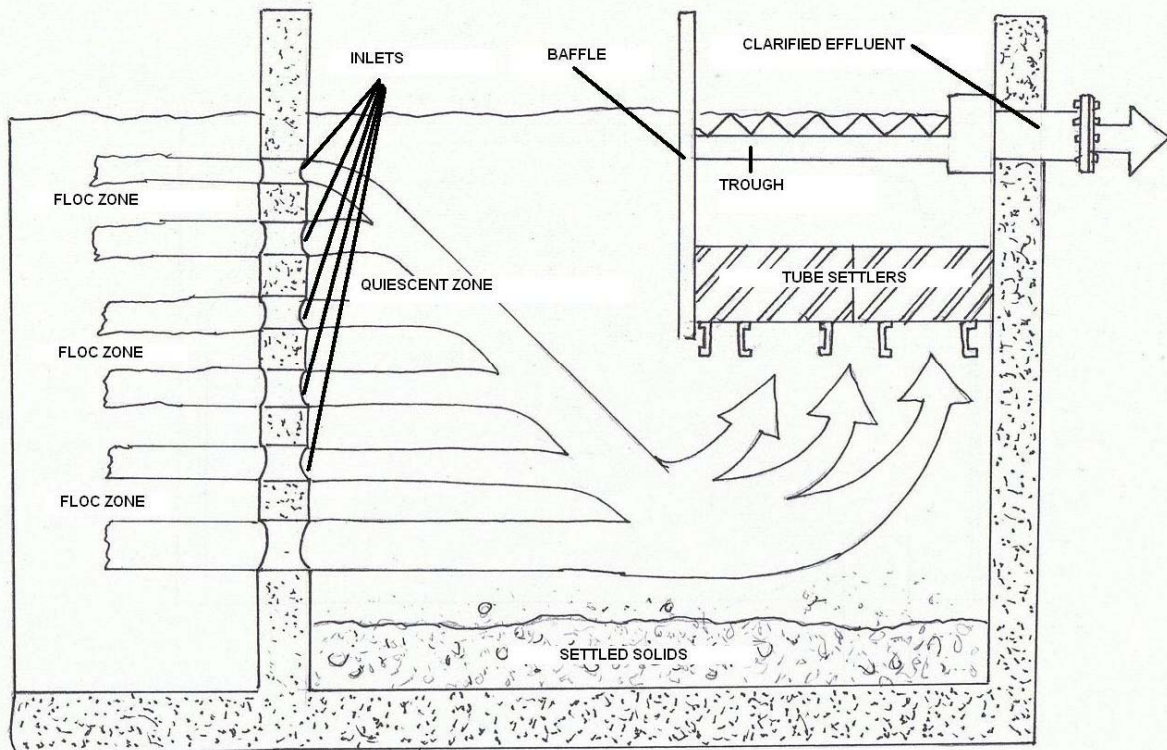
As a result of this litigation, the EPA promulgated the General Pretreatment Regulations at 40 CFR Part 403 on June 26, 1978, replacing the 40 CFR Part 128 requirements. Additionally, as a result of the suit, the EPA agreed to regulate the discharge of 65 categories of pollutants (making up the 126 priority pollutants presented in Figure 4) from 21 industrial categories. The list of priority pollutants is still in effect today (the original list actually had 129 pollutants, three of which have since been removed from that list) while the list of regulated industrial categories has grown to more than 51 distinct industries.



Modern wastewater treatment plant.



The National Pretreatment Program is unique in that the General Pretreatment Regulations require all large POTWs (i.e., those designed to treat flows of more than 5 million gallons per day) and smaller POTWs with significant industrial discharges to establish local pretreatment programs. These local programs must enforce all national pretreatment standards and requirements in addition to any more stringent local requirements necessary to protect site-specific conditions at the POTW.



General Pretreatment Regulations at 40 CFR Part 403§ 403.1 Purpose and Applicability

Figure 6. The General Pretreatment Regulations

§ 403.2 Objectives of general pretreatment regulations
§ 403.3 Definitions
§ 403.4 State or local law
§ 403.5 National pretreatment standards: Prohibited discharges
§ 403.6 National pretreatment standards: Categorical pretreatment standards
§ 403.7 Removal credits
§ 403.8 Pretreatment program requirements: Development and implementation by POTW
§ 403.9 POTW pretreatment programs and/or authorization to revise pretreatment standards: Submission for approval
§ 403.10 Development and submission of NPDES State pretreatment programs
§ 403.11 Approval procedures for POTW pretreatment programs and POTW granting of removal credits
§ 403.12 Reporting requirements for POTW's and industrial users
§ 403.13 Variances from categorical pretreatment standards for fundamentally different factors
§ 403.14 Confidentiality
§ 403.15 Net/Gross calculation
§ 403.16 Upset provision
§ 403.17 Bypass
§ 403.18 Modification of POTW pretreatment programs
Appendix A: Program Guidance Memorandum
Appendix B: [Reserved]
Appendix C: [Reserved]
Appendix D: Selected Industrial Subcategories Considered Dilute for Purposes of the Combined Wastestream Formula
Appendix E: Sampling Procedures
Appendix F: [Reserved]
Appendix G: Pollutants Eligible for a Removal Credit

The General Pretreatment Regulations

1. The General Pretreatment Regulations establish responsibilities of Federal, State, and local government, industry and the public to implement Pretreatment Standards to control pollutants which pass through or interfere with POTW treatment processes or which may contaminate sewage sludge. The regulations, which have been revised numerous times since originally published in 1978, consist of 18 sections and several appendices.
2. The General Pretreatment Regulations apply to all non-domestic sources which introduce pollutants into a POTW. These sources of “**indirect discharge**” are more commonly referred to as industrial users (**IUs**).

3. Since IUs can be as simple as an unmanned coin operated car wash to as complex as an automobile manufacturing plant or a synthetic organic chemical producer, EPA developed four criteria that define a Significant Industrial User (**SIU**). Many of the General Pretreatment Regulations apply to SIUs as opposed to IUs, based on the fact that control of SIUs should provide adequate protection of the POTW.

These four criteria are as follows:

- An IU that discharges an average of 25,000 gallons per day or more of process wastewater to the POTW;
- An IU that contributes a process wastestream making up 5 percent or more of the average dry weather hydraulic or organic capacity of the POTW treatment plant;
- An IU designated by the Control Authority as such because of its reasonable potential to adversely affect the POTW's operation or violate any pretreatment standard or requirement; or
- An IU subject to Federal categorical pretreatment standards.

Unlike other environmental programs that rely on Federal or State governments to implement and enforce specific requirements, the Pretreatment Program places the majority of the responsibility on local municipalities. Specifically, section 403.8(a) of the General Pretreatment Regulations states that any POTW (or combination of treatment plants operated by the same authority) with a total design flow greater than 5 million gallons per day (**MGD**) and smaller POTWs with SIUs must establish a local pretreatment program.

As of early 1998, 1,578 POTWs are required to have local programs. While this represents only about 15 percent of the total treatment plants nationwide, these POTWs account for more than 80 percent (i.e., approximately 30 billion gallons a day) of the national wastewater flow.

Control Authority

The General Pretreatment Regulations define the term “**Control Authority**” as a POTW that administers an approved pretreatment program since it is the entity authorized to control discharges to its system.

Section 403.10(e) provides States authority to implement POTW pretreatment programs in lieu of POTWs. Five States have elected to assume this responsibility (Vermont, Connecticut, Alabama, Mississippi, and Nebraska). In these instances, the State is defined as the Control Authority. As described above, all Control Authorities must establish a local pretreatment program to control discharges from non-domestic sources.

Approval Authority

These programs must be approved by the “**Approval Authority**” who is also responsible for overseeing implementation and enforcement of these programs.

A total of 44 States /Territories are authorized to implement State NPDES Permit Programs, but only 27 are authorized to be the Pretreatment Program Approval Authority (i.e., those with approved State pretreatment programs excluding the five §403.10(e) States). In all other States and Territories (including the 403.10(e) States), the EPA is considered to be the Approval Authority.

POTW Pretreatment Programs

The actual requirement for a POTW to develop and implement a local pretreatment program is a condition of its NPDES permit. Once the Approval Authority determines that a POTW needs a pretreatment program, the POTW's NPDES permit is modified to require development of a local program and submission of the program to the Approval Authority for review and approval. Consistent with §403.8(f), POTW pretreatment programs must contain the six minimum elements.

In addition to the six specific elements, pretreatment program submissions must include:

- a statement from the City Solicitor (or the like) declaring the POTW has adequate authority to carry out program requirements;
- copies of statutes, ordinances, regulations, agreements, or other authorities the POTW relies upon to administer the pretreatment program including a statement reflecting the endorsement or approval of the bodies responsible for supervising and/or funding the program;
- a brief description and organizational chart of the organization administering the program; and
- a description of funding levels and manpower available to implement the program.

Pretreatment program submissions found to be complete proceed to the public notice process, Public Participation and POTW Reporting. Upon program approval, the Approval Authority is responsible for modifying the POTW's NPDES permit to require implementation of the approved pretreatment program. Once approved, the Approval Authority oversees POTW pretreatment program implementation via receiving annual reports and conducting periodic audits and inspections.

As of early 1998, of the 1,578 POTWs required to develop pretreatment programs, 97 percent (1,535) have been approved. The National Pretreatment Program regulates IUs through three types of regulatory entities: the EPA, Approval Authorities, and Control Authorities. As noted above, Approval Authorities oversee Control Authorities while Control Authorities regulate IUs.



Using an extension pole with a sample attachment to grab a sample.

Approved State NPDES Permit Program Approved State Pretreatment Program

Alabama	10/19/79	10/19/79*
Arizona	Has program	
Arkansas	11/01/86	11/01/86
California	05/14/73	09/22/89
Colorado	03/27/75	--
Connecticut	09/26/73	06/03/81*
Delaware	04/01/74	--
Florida	05/01/95	05/01/95
Georgia	06/28/74	03/12/81
Hawaii	11/28/74	08/12/83
Illinois	10/23/77	--
Indiana	01/01/75	--
Iowa	08/10/78	06/03/81
Kansas	06/28/74	--
Kentucky	09/30/83	09/30/83
Louisiana	08/27/96	08/27/96
Maryland	09/05/74	09/30/85
Michigan	10/17/73	04/16/85
Minnesota	06/30/74	07/16/79
Mississippi	05/01/74	05/13/82*
Missouri	10/30/74	06/03/81
Montana	06/10/74	--
Nebraska	06/12/74	09/07/84*
Nevada	09/19/75	--
New Jersey	04/13/82	04/13/82
New York	10/28/75	--
North Carolina	10/19/75	06/14/82
North Dakota	06/13/75	--
Ohio	03/11/74	07/27/83
Oklahoma	11/19/96	11/19/96
Oregon	09/26/73	03/12/81
Pennsylvania	06/30/78	--
Rhode Island	09/17/84	09/17/84
South Carolina	06/10/75	04/09/82
South Dakota	12/30/93	12/30/93
Tennessee	12/28/77	08/10/83
Texas	09/14/98	09/14/98
Utah	07/07/87	07/07/87
Vermont	03/11/74	03/16/82*
Virgin Islands	06/30/76	--
Virginia	03/31/75	04/14/89
Washington	11/14/73	09/30/86
West Virginia	05/10/82	05/10/82
Wisconsin	02/04/74	12/24/80
Wyoming	01/30/75	--

* - Denotes 403.10(e) State Approval

Six Minimum Pretreatment Program Elements

1. Legal Authority (*see ordinance example in the rear*)

The POTW must operate pursuant to legal authority enforceable in Federal, State or local courts, which authorizes or enables the POTW to apply and enforce any pretreatment regulations developed pursuant to the CWA. At a minimum, the legal authority must enable the POTW to:

- i. deny or condition discharges to the POTW;
- ii. require compliance with pretreatment standards and requirements;
- iii. control IU discharges through permits, orders, or similar means;
- iv. require IU compliance schedules when necessary to meet applicable pretreatment standards and/or requirements and the submission of reports to demonstrate compliance;
- v. inspect and monitor IUs;
- vi. obtain remedies for IU noncompliance; and
- vii. comply with confidentiality requirements.

2. Procedures

The POTW must develop and implement procedures to ensure compliance with pretreatment requirements, including:

- i. identify and locate all IUs subject to the pretreatment program;
- ii. identify the character and volume of pollutants contributed by such users;
- iii. notify users of applicable pretreatment standards and requirements;
- iv. receive and analyze reports from IUs;
- v. sample and analyze IU discharges and evaluate the need for IU slug control plans;
- vi. investigate instances of noncompliance; and
- vii. comply with public participation requirements.

3. Funding

The POTW must have sufficient resources and qualified personnel to carry out the authorities and procedures specified in its approved pretreatment program.

4. Local limits

The POTW must develop local limits or demonstrate why these limits are not necessary.

5. Enforcement Response Plan (ERP)

The POTW must develop and implement an ERP that contains detailed procedures indicating how the POTW will investigate and respond to instances of IU noncompliance.

6. List of SIUs

The POTW must prepare, update, and submit to the Approval Authority a list of all Significant Industrial Users (**SIUs**).

Pretreatment Roles and Responsibilities

EPA Headquarters

- < Oversees program implementation at all levels
- < Develops and modifies regulations for the program
- < Develops policies to clarify and further define the program
- < Develops technical guidance for program implementation
- < Initiates enforcement actions as appropriate

Regions

- < Fulfill Approval Authority responsibilities for States without a State pretreatment program
- < Oversee State program implementation
- < Initiate enforcement actions as appropriate.

Approval Authorities (EPA Regions and delegated States)

- < Notify POTWs of their responsibilities
- < Review and approve requests for POTW pretreatment program approval or modification
- < Review requests for site-specific modifications to categorical pretreatment standards
- < Oversee POTW program implementation
- < Provide technical guidance to POTWs
- < Initiate enforcement actions, against noncompliant POTWs or industries.

Control Authorities (POTWs, States, or EPA Regions)

- < Develop, implement, and maintain approved pretreatment program
- < Evaluate compliance of regulated IUs
- < Initiate enforcement action against industries as appropriate
- < Submit reports to Approval Authorities
- < Develop local limits (or demonstrate why they are not needed)
- < Develop and implement enforcement response plan.

Industrial Users

- < Comply with applicable pretreatment standards and reporting requirements.

What Types of Businesses are Subject to Pretreatment Regulations?

Pretreatment regulations apply to a variety of businesses discharging wastewater from industrial and commercial processes.

Certain types of industries with the potential to discharge pollutants are regulated through an industrial discharge permit system. Industries are considered Significant Industrial Users and therefore require a discharge permit if the user:



- Is subject to the Environmental Protection Agency's Categorical Pretreatment Standards. Categorical users receive increased scrutiny due to their potential to pollute. Examples of categorical users are metal finishers and pharmaceutical manufacturers.
- Is discharging an average of 25,000 gallons per day or more of process wastewater.
- Has the potential to adversely affect the wastewater utility.

Industry-Specific Guides

Aluminum, Copper, And Nonferrous Metals Forming And Metal Powders

- Pretreatment Standards: A Guidance Manual
- Guidance Manual For Battery Manufacturing Pretreatment Standards
- Guidance Manual for Electroplating and Metal Finishing Pretreatment Standard
- Guidance Manual For Iron And Steel Manufacturing Pretreatment Standards
- Guidance Manual for Leather Tanning and Finishing Pretreatment Standards
- Guidance Manual for Pulp, Paper, Paperboard, Builders' Paper, and
- Board Mills Pretreatment Standards

Pretreatment Standards

The National Pretreatment Program identifies specific requirements that apply to all IUs, additional requirements that apply to all SIUs, and certain requirements that only apply to CIUs. The objectives of the National Pretreatment Program are achieved by applying and enforcing three types of discharge standards:

< ***prohibited discharge standards***

< ***categorical standards***

< ***local limits.***

Prohibited Discharge Standards

All IUs, whether or not subject to any other National, State, or local pretreatment requirements, are subject to the general and specific prohibitions identified in 40 CFR §§403.5(a) and (b), respectively. General prohibitions forbid the discharge of any pollutant(s) to a POTW that cause pass through or interference (Figure 10). Specific prohibitions forbid eight categories of pollutant discharges as follows:

- (1) discharges containing pollutants which create a fire or explosion hazard in the POTW, including but not limited to, wastestreams with a closed cup flashpoint of less than 140°F (60°C) using the test methods specified in 40 CFR §261.21;
- (2) discharges containing pollutants causing corrosive structural damage to the POTW, but in no case discharges with a pH lower than 5.0, unless the POTW is specifically designed to accommodate such discharges;
- (3) discharges containing pollutants in amounts causing obstruction to the flow in the POTW resulting in interference;
- (4) discharges of any pollutants released at a flow rate and/or concentration which will cause interference with the POTW;
- (5) discharges of heat in amounts which will inhibit biological activity in the POTW resulting in interference, but in no case heat in such quantities that the temperature at the POTW treatment plant exceeds 40°C (104°F) unless the Approval Authority, upon request of the POTW, approves alternative temperature limits;
- (6) discharges of petroleum oil, nonbiodegradable cutting oil, or products of mineral oil origin in amounts that will cause interference or pass through;
- (7) discharges which result in the presence of toxic gases, vapors, or fumes within the POTW in a quantity that may cause acute worker health and safety problems; and
- (8) discharges of trucked or hauled pollutants, except at discharge points designated by the POTW.

Compliance with the general and specific prohibitions is mandatory for all IUs, although a facility may have an affirmative defense in any action brought against it alleging a violation of the general prohibitions or of certain specific prohibitions [(3), (4), (5), (6) and (7) above] where the IU can demonstrate it did not have reason to know that its discharge, alone or in conjunction with a discharge or discharges from other sources, would cause pass through or interference, and the IU was in compliance with a technically-based local limit developed to prevent pass through or interference. These prohibited discharge standards are intended to provide general protection for POTWs. However, their lack of specific pollutant limitations creates the need for additional controls, namely categorical pretreatment standards and local limits.

Interference and Pass Through

Pass through - A discharge which exits the POTW into waters of the US in quantities or concentrations which, alone or in conjunction with a discharge or discharges from other sources, is a cause of a violation of any requirement of the POTW's NPDES permit (including an increase in the magnitude or duration of a violation).

Interference - A discharge which, alone or in conjunction with a discharge or discharges from other sources, both (1) inhibits or disrupts the POTW, its treatment processes or operations, or its sludge processes, use or disposal; and (2) therefore is a cause of a violation of any requirement of the POTW's NPDES permit or of the prevention of sewage sludge use or disposal.

Categorical Pretreatment Standards

Categorical pretreatment standards (i.e., categorical standards) are national, uniform, technology-based standards that apply to discharges to POTWs from specific industrial categories (i.e., **indirect dischargers**) and limit the discharge of specific pollutants. Categorical pretreatment standards for both existing and new sources (PSES and PSNS, respectively) are promulgated by the EPA pursuant to Section 307(b) and (c) of the CWA. Limitations developed for indirect discharges are designed to prevent the discharge of pollutants that could pass through, interfere with, or otherwise be incompatible with POTW operations. Effluent limitations guidelines (**ELGs**), developed in conjunction with categorical standards, limit the discharge from facilities directly to waters of the U.S. (i.e., **direct dischargers**) and do not apply to indirect dischargers.

ELGs include Best Practicable Control Technology Currently Available (**BPT**), Best Conventional Pollutant Control Technology (**BCT**), and Best Available Technology Economically Achievable (**BAT**) limitations and New Source Performance Standards (**NSPS**). ELGs (i.e., BPT, BCT, BAT, and NSPS) do not apply to indirect dischargers. The significant difference between categorical standards and effluent limitations guidelines is that categorical standards account for any pollutant removal that may be afforded through treatment at the POTW, while effluent limitations guidelines do not. Industries identified as major sources of toxic pollutants are typically targeted for effluent guideline and categorical standard development.

If limits are deemed necessary, the EPA investigates affected IUs and gathers information regarding process operations as well as treatment and management practices accounting for differences in facility size and age, equipment age, and wastewater characteristics.

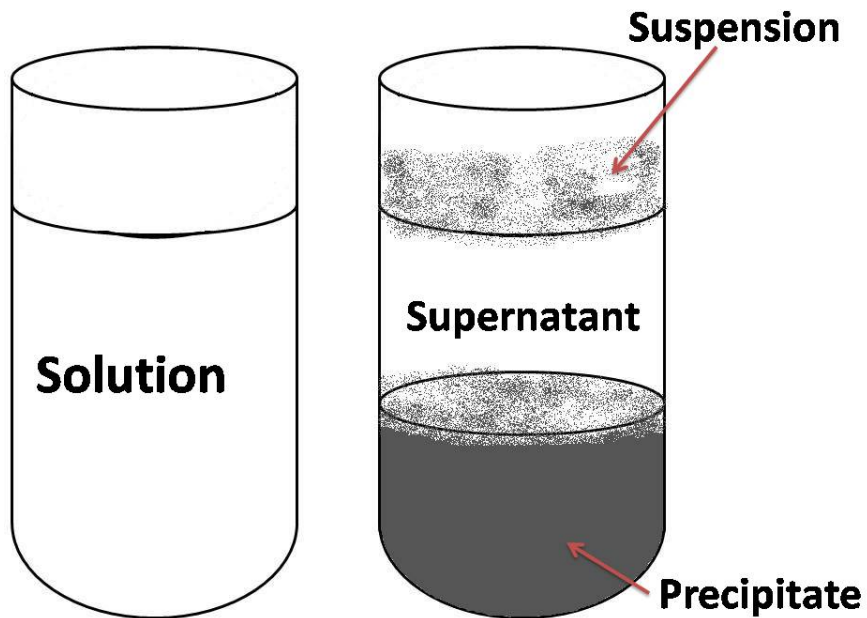
Sub categorization within an industrial category is evaluated based on variability in processes employed, raw materials used, types of items produced, and characteristics of wastes generated. Availability and cost of control technologies, non-water quality environmental impacts, available pollution prevention measures, and economic impacts are then identified prior to the EPA's presentation of findings in proposed development documents and publishing a notice of the proposed regulations in the *Federal Register*. Based on public comments on the proposed rule, the EPA promulgates (i.e., publishes) the standards.





Self-Monitoring

Sampling and analyses performed by a facility to ensure compliance with a permit or other regulatory requirements.



Definition of New Source (40 CFR 403.3(k))

New Source is defined at 40 CFR §403.3 (k)(1) to mean any building, structure, facility or installation from which there is or may be a discharge of pollutants, the construction of which commenced after publication of proposed Pretreatment Standards under Section 307(c) of the Act which will be applicable to such source if Standards are thereafter promulgated in accordance with that section, *provided that*:

(i) the building, structure, facility, or installation is constructed at a site at which no other source is located; or

(ii) the building, structure, facility, or installation totally replaces the process or production equipment that causes the discharge of pollutants at an existing source; or

(iii) the production or wastewater generating processes of the building, structure, facility or installation are substantially independent of an existing source at the same site. In determining whether these are substantially independent, factors such as the extent to which the new facility is integrated with the existing plant, and the extent to which the new facility is engaged in the same general type of activity as the existing source should be considered.

(2) Construction on a site at which an existing source is located results in a modification rather than a new source if the construction does not create a new building, structure, facility, or installation meeting the criteria of paragraphs (k)(1)(ii), or (k)(1)(iii) of this section but otherwise alters, replaces, or adds to existing process or production equipment.

(3) Construction of a new source as defined under this paragraph has commenced if the owner or operator has:

(i) begun, or caused to begin as part of a continuous onsite construction program:

(ii) any placement, assembly or installation of facilities or equipment, or

(B) significant site preparation work, including clearing, excavation, or removal of existing buildings, structures, or facilities which is necessary for the placement, assembly, or installation of new source facilities or equipment; or

(ii) entered into a binding contractual obligation for the purchase of facilities or equipment which are intended to be used in its operation within a reasonable time.

Options to purchase or contracts which can be terminated or modified without substantial loss, and contracts for feasibility, engineering, and design studies do not constitute a contractual obligation under this paragraph.

New Source

As noted above, categorical pretreatment standards are developed both for existing (**PSES**) and new sources (**PSNS**). Facilities are classified as either PSES or PSNS based on the definition of "**new source**" set out in 40 CFR§403.3(k) of the General Pretreatment Regulations. Dischargers subject to PSES are required to comply with those standards by a specified date, typically no more than three years after the effective date of the categorical standard. Users subject to PSNS, however, are required to achieve compliance within the shortest feasible time, not to exceed 90 days from commencement of discharge. PSNS are often more stringent than PSES based on the opportunity for new sources to install the best available demonstrated technology and operate the most efficient production processes.

Congress established an initial list of 21 categorical industries under Section 306 of the CWA of 1972. As a result of various court decrees and settlement agreements resulting from litigation, and from the EPA's internal work plan development process, the EPA has developed effluent guidelines (for direct dischargers) and/or categorical pretreatment standards (for indirect dischargers) for 51 industrial categories.

Of these industrial categories, the EPA implements pretreatment standards for 32 categories, and either requires compliance solely with 40 CFR Part 403 General Pretreatment Regulations or does not address pretreatment standards for the remaining categories.

Plans for the EPA's expansion and modification of the list is detailed in the *Effluent Guidelines Plan*, published in the *Federal Register* biennially as required in section 304(m) of the CWA. A list of the industrial categories that have categorical standards is provided as Figure 13. Categorical pretreatment standards developed can be concentration-based or mass-based.

Concentration-based standards are expressed as milligrams of pollutant allowed per liter (mg/l) of wastewater discharged and are issued where production rates for the particular industrial category do not necessarily correlate with pollutant discharges. Mass-based standards are generally expressed on a mass per unit of production (e.g., milligrams of pollutant per kilogram of product produced, pounds of pollutant per million cubic feet of air scrubbed, etc.) and are issued where water conservation is an important component in the limitation development process.

For a few categories where reducing a facility's flow volume does not provide a significant difference in the pollutant load discharged, the EPA has established both mass and concentration-based standards. Generally, both a daily maximum limitation and a long-term average limitation (e.g., average daily values in a calendar month) are established for every regulated pollutant.



Primary Wastewater Treatment Clarifier.

Summary of Categorical Pretreatment Standards *Figure 13*

Category	40 CFR Part	Subparts	Type of Standard Overview of Pretreatment Standards
Aluminum Forming	467 A-F	PSES PSNS	Limits are production-based, daily maximums and monthly averages. Subpart C prohibits discharges from certain operations.
Battery Manufacturing	461 A-G	PSES PSNS	Limits are production-based, daily maximums and monthly averages. No discharge is allowed from any process not specifically identified in the regulations.
Builders' Paper and Board Mills	431 A	PSES PSNS	Limits are production-based daily maximums. These facilities may certify they do not use certain compounds in lieu of performing monitoring to demonstrate compliance.
Carbon Black Manufacturing	458 A-D	PSNS	Limits are for Oil & Grease only (no limit duration specified).
Coil Coating	465 A-D	PSES PSNS	Limits are production-based, daily maximums and monthly averages.
Copper Forming	468 A	PSES PSNS	Limits are production-based, daily maximums and monthly averages.
Electrical and Electronic Components	469 A-D	PSES PSNS	Limits are concentration-based, daily maximums and 30 day averages or monthly averages (varies per subpart and pollutant parameter). Certification is allowed in lieu of monitoring for certain pollutants when a management plan is approved and implemented.
Electroplating	413 A-B, D-H	PSES	Limits are concentration-based (or alternative mass-based equivalents), daily maximums and four consecutive monitoring days averages. Two sets of limits exist, depending on if facility discharges more or less than 10,000 gallons per day of process wastewater. Certification is allowed in lieu of monitoring for certain pollutants when a management plan is approved and implemented.
Feedlots	412 B	PSNS	Discharge of process wastewater is prohibited, except when there is an overflow resulting from a chronic or catastrophic rainfall event.
Fertilizer Manufacturing	418 A-G	PSNS	Limits may specify zero discharge of wastewater pollutants (Subpart A), production-based daily maximums and 30-day averages (Subparts B-E) or concentration-based (Subparts F-G) with no limit duration specified.
Glass Manufacturing	426 H, K-M	PSNS	Limits are either concentration- or production-based, daily maximums and monthly averages.
Grain Mills	406 A	PSNS	Discharge of process wastewater is prohibited at a flow rate or mass loading rate which is excessive over any time period during the peak load at a POTW.
Ink Formulating	447 A	PSNS	Regulations specify no discharge of process wastewater pollutants to the POTW.
Inorganic Chemicals Manufacturing	415 A-BO	PSES PSNS	Limits vary for each subpart with a majority of the limits concentration-based, daily maximums and 30-day averages, or may specify no discharge of wastewater pollutants. Numerous subparts have no pretreatment standards.
Iron and Steel Manufacturing	420 A-F, H-J, L	PSES PSNS	Limits are production-based, daily maximums and 30 day averages.
Leather Tanning and Finishing	425 A-I	PSES PSNS	Limits are concentration-based, daily maximums and monthly averages. In certain instances, production volume dictates applicable pretreatment standards.
Metal Finishing	433 A	PSES PSNS	Limits are concentration-based, daily maximums and monthly averages. Certification is allowed for certain pollutants where a management plan is approved and implemented.
Metal Molding and Casting	464 A-D	PSES PSNS	Limits are primarily production-based, daily maximums and monthly averages. Discharges from certain processes are prohibited (Subparts A-C).
Nonferrous Metals Forming and Metal Powders	471 A-J	PSES PSNS	Limits are production-based, daily maximums and monthly averages. In some instances, the regulations prohibit the discharge of wastewater pollutants.
Nonferrous Metals Manufacturing	421 B-AE	PSES PSNS	Limits are production-based, daily maximums and monthly averages. The majority of the Subparts have both existing and new source limits, with others having solely new source requirements.

Summary of Categorical Pretreatment Standards *Figure 13*

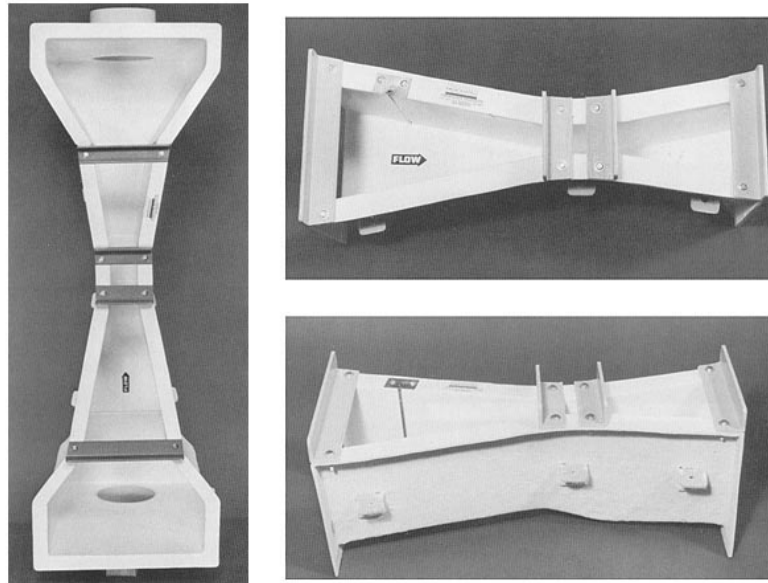
Organic Chemicals, Plastics, and Synthetic Fibers	414 B-H, K	PSES PSNS	Limits are mass-based (concentration-based standards multiplied by process flow), daily maximums and monthly averages. Standards for metals and cyanide apply only to metal- or cyanide-bearing wastestreams.
Paint Formulating	446 A	PSNS	Regulations specify no discharge of process wastewater pollutants to the POTW.
Paving and Roofing Materials (Tars and Asphalt)	443 A-D	PSNS	Limits are for Oil & Grease only (no limit duration specified).
Pesticide Chemicals	455 A, C, E	PSES PSNS	Limits are mass-based (concentration-based standards multiplied by process flow), daily maximums and monthly averages. Subpart C specifies no discharge of process wastewater pollutants but provides for pollution prevention alternatives. Subpart E specifies no discharge of process wastewater pollutants.
Petroleum Refining	419 A-E	PSES PSNS	Limits are concentration-based (or mass based equivalent), daily maximums.
Pharmaceutical Manufacturing	439 A-D	PSES PSNS	Limits are concentration-based, daily maximums and monthly averages. These facilities may certify they do not use or generate cyanide in lieu of performing monitoring to demonstrate compliance.
Porcelain Enameling	466 A-D	PSES PSNS	Limits are concentration-based (or alternative production-based), daily maximums and monthly averages. Subpart B prohibits discharges certain operations.
Pulp, Paper, and Paperboard	430 A-G, I-L	PSES PSNS	Limits are production-based daily maximums and monthly averages. These facilities may certify they do not use certain compounds in lieu of performing monitoring to demonstrate compliance. Facilities subject to Subparts B and E must also implement Best Management Practices as identified.
Rubber Manufacturing	428 E-K	PSNS	Limits are concentration- or production-based, daily maximums and monthly averages.
Soap and Detergent Manufacturing	417 O-R	PSNS	Regulations specify no discharge of process wastewater pollutants to the POTW.
Steam Electric Power Generating	423 N/A	PSES PSNS	Limits are either concentration-based, daily maximums, or "maximums for any time", or compliance can be demonstrated through engineering calculations.
Timber Products Processing	429 F-H	PSES PSNS	All PSNS (and PSES for Subpart F) prohibit the discharge of wastewater pollutants. PSES for Subparts G and H are concentration-based, daily maximums (with production-based alternatives).

CWF vs. FWA

Categorical standards apply to regulated wastewaters, i.e. wastewater from an industrial process that is regulated for a particular pollutant by a categorical pretreatment standard. Therefore, demonstrating compliance with categorical pretreatment standards is intended to be based on measurements of wastestreams containing only the regulated process wastewater. However, recognizing isolation of regulated wastestreams from nonregulated wastestreams was not always practicable or desirable, the EPA developed the combined wastestream formula (**CWF**) and flow weighted average (**FWA**) approach for determining compliance with combined wastestreams.

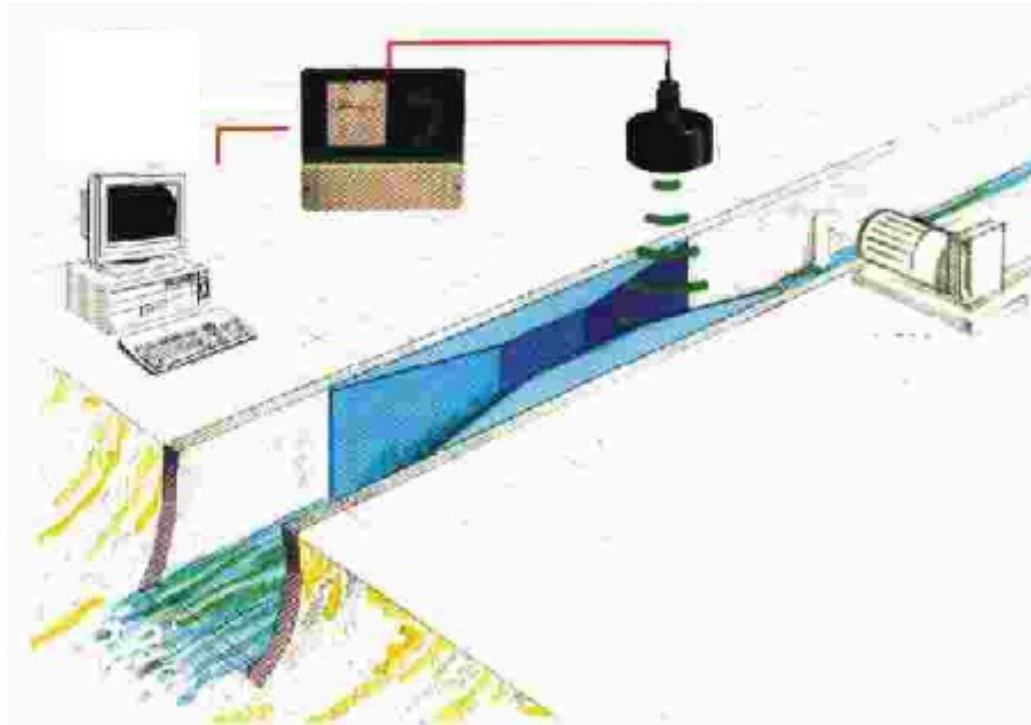
Pursuant to 40 CFR §403.6(e), the CWF is applicable where a regulated wastestream combines with one or more unregulated or dilute wastestreams prior to treatment. Where nonregulated wastestreams combine with process streams after pretreatment, the more stringent approach (whether CWF or FWA) is used to adjust the limits. The CWF and FWA approaches differ primarily in their allowances for nonregulated wastestreams. While the CWF provides a **“full credit”** (i.e., same pollutant levels as regulated wastestreams) for unregulated wastestreams yet no credit for dilute wastestreams, the FWA requires sampling and analysis of the untreated, nonregulated wastestreams to determine the credit to be granted (not to exceed that allowed for the regulated wastestreams).

Application of the CWF and FWA requires proper identification, classification, and quantification of the three wastestream types (Figure 16.) **Note:** in circumstances where boiler blowdown, noncontact cooling water, stormwater, or demineralized wastestreams contain a significant amount of a regulated pollutant, and the treatment of the wastewater with the regulated wastestream results in substantial reduction of the regulated pollutant, the Control Authority can classify the wastestream as unregulated rather than as a dilute wastestream.



Measuring device known as a “Parshall Flume”.

Several POTW’s are requiring the SIU to cover the flume inside the vault to lower the hazard of a permit required confined space.



Ultra-sonic measuring device at the entrance of the flume. Data is stored directly to the computer or data recording device.

Parshall Flumes

Parshall Flume provides both accuracy and rangeability. Dimensions and capacities are in accordance with those published in the U.S. Department of the Interior's Water Measurement Manual.

Parshall Flumes are a primary flow element for flow measurement in open channels. The big advantages of Parshall Flumes are their self-cleaning capabilities, low head loss, single-head measurement, and wide operating range.

While commonly used in rectangular channels, they can also be adapted for use in circular channels. Flumes feature stiffening ribs, braces and anchor clips. Options include stilling well, staff gauge, flow sensors, adaptors, etc.

Clarification

Clarification on category-specific wastestream classifications may be provided by consulting the applicable regulation(s) and associated development documents, since wastestream types are addressed in the effluent guideline and categorical standard development process. When in doubt, the Control Authority can always require the CIU to monitor the wastestream(s) in question to quantify the presence (or lack thereof) of categorically regulated pollutants.

Reasonably accurate flow data must also be obtained for each wastestream type flowing through the monitoring point to ensure categorical pretreatment standards are adjusted accordingly.

Proper application of the CWF or FWA will result in:

- alternative limits being established for each regulated pollutant in each regulated process;
- both daily maximum and long-term average (i.e., 4-day, 30-day, or monthly) alternative limits being calculated for each regulated pollutant;

Figure 16. Wastestream Types

Regulated

Wastewater from an industrial process that is regulated for a particular pollutant by a categorical pretreatment standard.

Nonregulated, Unregulated

Wastestreams from an industrial process that are not regulated for a particular pollutant by a categorical pretreatment standard and are not defined as a dilute wastestream, e.g.:

< a process wastestream for which categorical standards have been promulgated but for which the deadline for compliance has not yet been reached.

< a process wastestream that currently is not subject to categorical pretreatment standards

< a process wastestream that is not regulated for the pollutant in question but is regulated for other pollutants.

Dilute

Wastestreams which have no more than trace or non-detectable amounts of the regulated pollutant. Defined in 40 CFR § 403.6(e)(1) of the General Pretreatment Regulations to include sanitary wastestreams, demineralized backwash streams, boiler blowdown, noncontact cooling water, storm water, and process wastestreams from certain standards based on the findings that these wastewaters contained none of the regulated pollutant or only trace amounts of it.

The EPA's *Guidance Manual for the Use of Production Based Pretreatment Standards and the Combined Wastestream Formula* should be consulted for more information on the proper application and adjustment of categorical pretreatment standards.

Although categorical standards are established based on a particular industrial category, the EPA provides several options for unique circumstances that justify adjustment of categorical standards for an individual facility:

**CHECKLIST EXAMPLE FOR ASSESSMENT OF
PERMANENTLY INSTALLED FLOWMETERS**

COMPANY NAME:		TYPE OF PRIMARY DEVICE:
SITE CODE #		SIZE:
ADDRESS:		
DIMENSIONS OF VAULT:	DEPTH OF VAULT:	

TAKE PICTURES!

1. IS FLUME LEVEL?
2. HEIGHT MEASUREMENT FROM TOP OF FLUME TO BOTTOM OF PERMANENT TRANSDUCER:
3. HOW HIGH DOES THE LEVEL GET IN FLUME?
4. DAILY MAXIMUM FLOW (CONVERTED TO LEVEL):
5. CAN YOU SETUP OUR TRANSDUCER UNDER OR NEXT TO THEIRS, WITHOUT DISTURBING THEIRS?
6. IS THEIR PERMANENT TRANSDUCER SETUP OVER THE PROPER MEASURING POINT ON THE FLUME?
7. RECORD ANY PROBLEMS WITH THE WAY THE PERMANENT TRANSDUCER / FLOWMETER IS SETUP:
8. COMMENTS_____

Removal Credits

40 CFR §403.7 details the conditions by which a Control Authority may demonstrate consistent removal of pollutants regulated by categorical standards at their POTW, and in so doing, may extend removal credits to industries on a pollutant-specific basis to prevent redundant treatment. Removal credits are available for a pollutant if the pollutant is regulated by the sewage sludge use or disposal option employed by the POTW making the application request, or if the pollutant is listed in 40 CFR Part 403, Appendix G.

Also, the availability of removal credits is not limited to Appendix G pollutants for POTWs that dispose of sewage sludge in municipal solid waste landfills. Steps for developing such a request are in the EPA's *Guidance Manual for the Preparation and Review of Removal Credit Applications*.

Fundamentally Different Factors Variance Section 301(n) of the CWA authorizes adjustments of categorical pretreatment standards for existing sources who demonstrate they have factors which are fundamentally different from the factors the EPA considered during standards development (40 CFR §403.13). Variance requests must be based solely on information and data submitted during the development of the categorical standards and the adjusted effluent limitations must neither be more nor less stringent than justified by the fundamental difference nor result in a non-water quality environmental impact markedly more adverse than the impact considered by the EPA when developing the categorical standard.

Successful requests must detail factors well outside the range considered by the EPA in establishing the standard and not merely factors deviating from the average. Further, differences must not be similar to a significant number of other facilities in the category. A facility must request a variance in writing no later than 180 days after publication of a categorical Pretreatment Standard in the Federal Register.

Net/Gross Adjustment Categorical Pretreatment Standards

Net/Gross Adjustment Categorical pretreatment standards can be adjusted to reflect the presence of pollutants in a CIU's intake waters (40 CFR §403.15). To obtain a net/gross credit, the CIU must submit a formal written request to the Control Authority that demonstrates:

- Its intake water is drawn from the same body of water that the POTW discharges into (this can be waived if the Control Authority finds no environmental degradation will result);
- The pollutants present in the intake water will not be entirely removed by the treatment system operated by the CIU; and
- The pollutants in the intake water do not vary chemically or biologically from the pollutants limited by the applicable standard.

Inherent in this provision is the requirement that the CIU employ a treatment technology capable of meeting the categorical pretreatment standard(s). Net/gross adjustments should not be granted to CIUs that have no treatment. Further, credits are only granted to the extent necessary to meet the applicable standard(s), up to a maximum value equal to the influent value.

Innovative Technology--in accordance with 307(e) of the CWA, existing CIUs choosing to install an innovative treatment system may receive approval from the Control Authority for up to a two year extension to their applicable categorical pretreatment standards compliance deadline, provided:

- The innovative treatment has a reasonable potential to result in significantly greater pollutant removal or equivalent removal at a substantially lower cost than the technologies considered by the EPA when developing the categorical standard;
- The innovative technique has the potential for industry-wide application; and
- The proposed compliance extension will not cause or contribute to the violation of the POTW's NPDES permit.

While policy has been established for universal categorical variance requests, occasionally, a Control Authority may merely need assistance to classify a CIU and/or to determine applicable categorical limitations. Provisions in the General Pretreatment Regulations allow POTWs and IUs to request an EPA category determination for a specific IU within 60 days after the effective date of the standard in question [40 CFR §403.6(a)].

Even after the formal timeframe for requesting a categorical determination, the EPA (and states) will assist POTWs and IUs with categorization issues. Such requests, however, do not affect applicable reporting requirements, including timely requests submitted under 40 CFR §403.6(a). Additionally, the EPA has addressed universal CIU questions posed by Control Authorities in various memoranda and guidance:

Research and Development (R&D) Facilities

Unless specifically addressed in the categorical regulation or associated development document, R&D facilities where there is no commercial sale of products from the facility, are not subject to categorical standards.

Should an R&D facility need pollution controls to comply with prohibited discharge standards and/or local limits, the development documents may serve as guidance on the performance of pollution control technologies.

Certification Statements

In lieu of requiring self-monitoring, some standards allow CIUs to certify that they do not use, generate or discharge a regulated pollutant [e.g. Pulp, Paper and Paperboard facilities can certify that chlorophenolic compounds are not used (40 CFR Part 430) and Pharmaceutical Manufacturing facilities can certify that cyanide is not used or generated (40 CFR Part 439)]. Facilities providing such certifications are still considered CIUs, and therefore are subject to other pretreatment standards and requirements.

Lack of specific categorical effluent limitations IUs subject to PSES or PSNS that merely require compliance with 40 CFR Part 403 are not considered CIUs. However, these users may still be classified as SIUs and are still subject to the general and specific prohibitions and any local limits.

Total Toxic Organics (TTO)

Seven categorical regulations currently limit the discharge of TTO:

- 40 CFR Part 413 - Electroplating
- 40 CFR Part 433 - Metal Finishing
- 40 CFR Part 464 - Metal Molding and Casting
- 40 CFR Part 465 - Coil Coating
- 40 CFR Part 467 - Aluminum Forming
- 40 CFR Part 468 - Copper Forming
- 40 CFR Part 469 - Electrical and Electronic Components (Phase I and II)

For each of these standards, TTO refers to the sum of the masses or concentrations of certain toxic organic pollutants found in the regulated discharge at a concentration greater than 0.01 milligrams per liter (mg/l).

However, the toxic organic pollutants regulated by the TTO limit are specific to each industrial category. Further, industrial categories may provide some flexibility with regard to monitoring and/or reporting requirements as follows:

40 CFR Parts 413 and 433 allow development and implementation of a Toxic Organic Management Plan (**TOMP**) in lieu of routine monitoring while 40 CFR Part 469 allows development and implementation of a Solvent Management Plan. Upon approval of these plans by the Control Authority, the CIU can demonstrate compliance with TTO requirements by certifying that the facility is adhering to this Plan to prevent organics from being discharged to the POTW. A specific certification statement must be signed and provided to the Control Authority on a regular basis.

40 CFR Parts 464, 465, 467, and 468 allow an option to demonstrate compliance with an Oil and Grease limit in lieu of demonstrating compliance with a TTO limit. The option chosen by the CIU must be utilized for all reports required (i.e., BMR, 90-day compliance report, and periodic compliance reports).

The EPA's *Guidance Manual for Implementing Total Toxic Organics (TTO) Pretreatment Standards* should be consulted for more information on TTO.



MAHL MAIL

Maximum Allowable Headworks Loading Method (MAHL)

Pollutant by pollutant, treatment plant data are used to calculate removal efficiencies, before applying the most stringent criteria (i.e., water quality, sludge quality, NPDES permit, or pollutant inhibition levels) to back-calculate the MAHLs. Subtracting out contributions from domestic sources, the available industrial loading is then either evenly distributed among the IUs, or allocated on an as needed basis to those IUs discharging the pollutant above background levels.

Maximum Allowable Industrial Load (MAIL)

The MAIL is the total daily mass that a POTW can accept from all permitted IUs and ensure the POTW is protecting against pass through and interference.



Headworks' "Rotating Barscreens"



Headworks flooding or overflowing because of high grease loading.

LOCAL LIMITS OBSERVATION SHEET *Example*

SITE DESCRIPTION:

SITE CODE #:

DATE:

TIME	pH	TEMP.	RES.CL ₂	INITIALS
0900				
1200				
1430				
1700				
2000				
2230				
0100				
0430				

DAILY TOTAL FLOW:

PICKLE JAR IW#	
FIELD COMP IW#	
VOC's IW#	
TPH IW#	

SAMPLES COLLECTED

PARAMETER	YES	NO	PARAMETER	YES	NO
601/602 (HOW MANY)			BOD, COD, TSS		
8240 (HOW MANY)			NO ₂ /NO ₃		
SULFIDES			METALS		
TKN			608		
AMMONIA (NH ₄)			1657		
CN			625		
TPH (HOW MANY)			8270		
8140			8080		

IF NO SAMPLE COLLECTED, RECORD ON BACK AS TO WHY.

More on Local Limits

Prohibited discharge standards are designed to protect against pass-through and interference generally. Categorical pretreatment standards, on the other hand, are designed to ensure that IUs implement technology-based controls to limit the discharge of pollutants. Local limits, however, address the specific needs and concerns of a POTW and its receiving waters.

Federal regulations at 40 CFR §§403.8(f)(4) and 122.21(j)(4) require Control Authorities to evaluate the need for local limits and, if necessary, implement and enforce specific limits as part of pretreatment program activities. Local limits are developed for pollutants (e.g. metals, cyanide, BOD5 TSS, oil and grease, organics) that may cause interference, pass through, sludge contamination, and/or worker health and safety problems if discharged in excess of the receiving POTW treatment plant's capabilities and/or receiving water quality standards.

Typically, local limits are developed to regulate the discharge from all IUs, not just to CIUs, and are usually imposed at the **"end-of-pipe"** discharge from an IU (i.e., at the point of connection to the POTW's collection system). In evaluating the need for local limit development, it is recommended that Control Authorities:

- Conduct an industrial waste survey to identify all IUs that might be subject to the pretreatment program;
- Determine the character and volume of pollutants contributed to the POTW by these industries;
- Determine which pollutants have a reasonable potential for pass through, interference, or sludge contamination;
- Conduct a technical evaluation to determine the maximum allowable POTW treatment plant headworks (influent) loading for at least arsenic, cadmium, chromium, copper, cyanide, lead, mercury, nickel, silver, and zinc (Figure19);
- Identify additional pollutants of concern;
- Determine contributions from unpermitted sources to determine the maximum allowable treatment plant headworks loading from "controllable" industrial sources (Figure 20);
- Implement a system to ensure these loadings will not be exceeded.

Other local limit approaches available to Control Authorities include:

Collection System Approach Pollutants found to be present which may cause fire and explosion hazards or other worker health and safety concerns, are evaluated for their propensity to volatilize and are modeled to evaluate their expected concentration in air. Comparisons are made with worker health exposure criteria and lower explosive limits. Where values are of concern, the Control Authority may set limits or require development of management practices to control undesirable discharges. The collection system approach may also consider the prohibition of pollutants with specific flashpoints to prevent discharges of ignitable wastes. The EPA's *Guidance to Protect POTW Workers from Toxic and Reactive Gases and Vapors* details strategies for developing such local limits.

Industrial User Management Practice Plans

These plans typically consist of narrative local limits requiring IUs to develop management practices (e.g., chemical management practices, best management practices, and spill prevention plans) for the handling of chemicals and wastes.

The need for and suggested contents of such plans may be found in the EPA's *Control of Slug Loadings to POTWs: Guidance Manual*, and *Spill Prevention, Control, and Countermeasure (SPCC) Information Guide*.

Case-by-Case Discharge Limits

These numeric local limits are based on best professional judgment (**BPJ**) and available pollution prevention and treatment technologies which are known to be economically feasible. This approach is most often used when insufficient data are available to employ the methods outlined above.

Local Specific Prohibitions

POTW specific prohibitions may be imposed in addition to the prohibitions detailed in 40 CFR § 403.5 (a) & (b) to address hydraulic, pollutant specific, and/or aesthetic concerns; e.g.:

- Noxious or malodorous liquids, gases, or solids creating a public nuisance.
- Wastestreams which impart color and pass through the POTW treatment plant.
- Storm water, roof runoff, swimming pool drainage.
- Wastewaters containing radioactive wastes or isotopes.
- Removed substances from pretreatment of wastewater.

Regardless of the approaches taken by a Control Authority, local limits should correct existing problems, prevent potential problems, protect the receiving waters, improve sludge use options, and protect POTW personnel. Additional existing EPA guidance on the subject includes:

- *Guidance for Preventing Interference at POTWs*
- *Guidance Manual on the Development and Implementation of Local Discharge Limitations Under the Pretreatment Program*
- *Supplemental Manual on the Development and Implementation of Local Discharge Limitations Under the Pretreatment Program: Residential and Commercial Toxic Pollutant Loadings and POTW Removal Efficiency Estimation*
- *Toxicity Identification Evaluation: Characterization of Chronically Toxic Effluents.*



Additionally, many EPA Regions and States have developed local limits guidance to address regional and state issues.

Summary of Standards

A summary of all of the pretreatment standards, including general and specific prohibitions, categorical pretreatment standards, and local limits.

	General and Specific Prohibitions	Categorical Pretreatment Standards	Local Limits
Development	Established at the Federal level	Established at the Federal level	Developed by Control Authorities
Reference	40 CFR 403.5(a) & (b)	40 CFR Parts 405-471	Requirements for development found in 40 CFR §§403.5(c) & 403.8(f)(4)
Applicability	All IUs	CIUs	Commonly all IUs or all SIUs, but depends on allocation method used when developing limits.
Purpose	Provide for general protection of the POTW. May be superseded by more stringent categorical pretreatment standards or local limits.	Minimum standards based on available treatment technology and pollution prevention measures for controlling non-conventional and toxic pollutants that may cause pass through, interference, etc. at the POTW. May be superseded by more stringent local limits.	Provide site specific protection for a POTW and its receiving waters. May be superseded by more stringent categorical standards.
All standards are considered pretreatment standards for the purpose of section 307(d) of the Clean Water Act. A POTW is responsible for identifying standard(s) applicable to each industrial user and applying the most stringent requirements where multiple provisions exist. Compliance with imposed standards can be achieved through implementation of best management practices, development of a pollution prevention program, and/or installation of pretreatment.			

Periodic Table of the Elements

1 New Original

18 VIIIA

1 IA 2 IIA

3 4 5 6 7 8 9 10 11 12

13 IIIA 14 IVA 15 VA 16 VIA 17 VIIA

Alkali metals
Alkaline earth metals
Transition metals
Lanthanide series

Actinide series
Poor metals
Nonmetals
Noble gases

Solid
Liquid
Gas
Synthetic

Atomic masses in parentheses are those of the most stable or common isotope.

Note: The subgroup numbers 1-18 were adopted in 1984 by the International Union of Pure and Applied Chemistry. The names of elements 112-118 are the Latin equivalents of those numbers.



Left, Tellurium, right Astatine with Fluorine



Common water sample bottles for distribution systems.

Radiochemicals, VOCs, (Volatile Organic Compounds), TTHMs, Total Trihalomethanes), Nitrate, Nitrite.

Most of these sample bottles will come with the preservative already inside the bottle.

Some bottles will come with a separate preservative (acid) for the field preservation.

Slowly add the acid or other preservative to the water sample; not water to the acid or preservative.

Inorganic Chemicals

Contaminant	MCLG ¹ (mg/L) ²	MCL or TT ¹ (mg/L) ²	Potential Health Effects from Long-Term Exposure Above the MCL (unless specified as short-term)	Sources of Contaminant in Drinking Water
Antimony	0.006	0.006	Increase in blood cholesterol; decrease in blood sugar	Discharge from petroleum refineries; fire retardants; ceramics; electronics; solder
Arsenic	0 ²	0.010 as of 01/23/06	Skin damage or problems with circulatory systems, and may have increased risk of getting cancer	Erosion of natural deposits; runoff from orchards, runoff from glass & electronics production wastes
Asbestos (fiber >10 micrometers)	7 million fibers per liter	7 MFL	Increased risk of developing benign intestinal polyps	Decay of asbestos cement in water mains; erosion of natural deposits
Barium	2	2	Increase in blood pressure	Discharge of drilling wastes; discharge from metal refineries; erosion of natural deposits
Beryllium	0.004	0.004	Intestinal lesions	Discharge from metal refineries and coal-burning factories; discharge from electrical, aerospace, and defense industries
Cadmium	0.005	0.005	Kidney damage	Corrosion of galvanized pipes; erosion of natural deposits; discharge from metal refineries; runoff from waste batteries and paints
Chromium (total)	0.1	0.1	Allergic dermatitis	Discharge from steel and pulp mills; erosion of natural deposits
			Short term exposure: Gastrointestinal distress	
Copper	1.3	TT ² ; Action Level=1.3	Long term exposure: Liver or kidney damage People with Wilson's Disease should consult their personal doctor if the amount of copper in their water exceeds the action level	Corrosion of household plumbing systems; erosion of natural deposits
Cyanide (as	0.2	0.2	Nerve damage or thyroid problems	Discharge from

Inorganic Chemicals

Contaminant	MCLG ¹ (mg/L) ²	MCL or TT ¹ (mg/L) ²	Potential Health Effects from Long-Term Exposure Above the MCL (unless specified as short-term)	Sources of Contaminant in Drinking Water
free cyanide)				steel/metal factories; discharge from plastic and fertilizer factories
Fluoride	4.0	4.0	Bone disease (pain and tenderness of the bones); Children may get mottled teeth	Water additive which promotes strong teeth; erosion of natural deposits; discharge from fertilizer and aluminum factories
Lead	zero	TT ² ; Action Level=0.015	Infants and children: Delays in physical or mental development; children could show slight deficits in attention span and learning abilities Adults: Kidney problems; high blood pressure	Corrosion of household plumbing systems; erosion of natural deposits
Mercury (inorganic)	0.002	0.002	Kidney damage	Erosion of natural deposits; discharge from refineries and factories; runoff from landfills and croplands
Nitrate (measured as Nitrogen)	10	10	Infants below the age of six months who drink water containing nitrate in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome.	Runoff from fertilizer use; leaking from septic tanks, sewage; erosion of natural deposits
Nitrite (measured as Nitrogen)	1	1	Infants below the age of six months who drink water containing nitrite in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome.	Runoff from fertilizer use; leaking from septic tanks, sewage; erosion of natural deposits
Selenium	0.05	0.05	Hair or fingernail loss; numbness in fingers or toes; circulatory problems	Discharge from petroleum refineries; erosion of natural deposits; discharge from mines
Thallium	0.0005	0.002	Hair loss; changes in blood; kidney, intestine, or liver problems	Leaching from ore-processing sites; discharge from electronics, glass, and drug factories

Antimony - Inorganic Contaminant 0.006 mg/L Water MCL Metalloid

Antimony is a toxic chemical element with symbol **Sb** and atomic number 51. A lustrous gray metalloid, it is found in nature mainly as the sulfide mineral stibnite (Sb_2S_3). Antimony compounds have been known since ancient times and were used for cosmetics; metallic antimony was also known, but it was erroneously identified as lead. It was established to be an element around the 17th century.

For some time, China has been the largest producer of antimony and its compounds, with most production coming from the Xikuangshan Mine in Hunan. The industrial methods to produce antimony are roasting and subsequent carbothermal reduction or direct reduction of stibnite with iron.

What are EPA's drinking water regulations for antimony?

In 1974, Congress passed the Safe Drinking Water Act. This law requires EPA to determine the level of contaminants in drinking water at which no adverse health effects are likely to occur. These non-enforceable health goals, based solely on possible health risks and exposure over a lifetime with an adequate margin of safety, are called maximum contaminant level goals (MCLG). Contaminants are any physical, chemical, biological or radiological substances or matter in water.



The MCLG for antimony is 0.006 mg/L or 6 ppb. EPA has set this level of protection based on the best available science to prevent potential health problems. EPA has set an enforceable regulation for antimony, called a maximum contaminant level (MCL), at 0.006 mg/L or 6 ppb. MCLs are set as close to the health goals as possible, considering cost, benefits and the ability of public water systems to detect and remove contaminants using suitable treatment technologies. In this case, the MCL equals the MCLG, because analytical methods or treatment technology do not pose any limitation.

The Phase V Rule, the regulation for antimony, became effective in 1994. The Safe Drinking Water Act requires EPA to periodically review the national primary drinking water regulation for each contaminant and revise the regulation, if appropriate. EPA reviewed antimony as part of the Six Year Review and determined that the 0.006 mg/L or 6 ppb MCLG and 0.006 mg/L or 6 ppb MCL for antimony are still protective of human health.

Applications

The largest applications for metallic antimony are as alloying material for lead and tin and for lead antimony plates in lead-acid batteries. Alloying lead and tin with antimony improves the properties of the alloys which are used in solders, bullets and plain bearings. Antimony compounds are prominent additives for chlorine- and bromine-containing fire retardants found in many commercial and domestic products. An emerging application is the use of antimony in microelectronics.

Antimony is in the nitrogen group (group 15) and has an electronegativity of 2.05. As expected by periodic trends, it is more electronegative than tin or bismuth, and less electronegative than tellurium or arsenic. Antimony is stable in air at room temperature, but reacts with oxygen if heated to form antimony trioxide, Sb_2O_3 . Antimony is a silvery, lustrous gray metal that has a Mohs scale hardness of 3. Therefore, pure antimony is not used to make hard objects: coins made of antimony were issued in China's Guizhou province in 1931, but because of their rapid wear, their minting was discontinued. Antimony is resistant to attack by acids.

Four allotropes of antimony are known, a stable metallic form and three metastable forms, explosive, black and yellow. Metallic antimony is a brittle, silver-white shiny metal. When molten antimony is slowly cooled, metallic antimony crystallizes in a trigonal cell, isomorphic with that of the gray allotrope of arsenic. A rare explosive form of antimony can be formed from the electrolysis of antimony (III) trichloride. When scratched with a sharp implement, an exothermic reaction occurs and white fumes are given off as metallic antimony is formed; when rubbed with a pestle in a mortar, a strong detonation occurs.

Black antimony is formed upon rapid cooling of vapor derived from metallic antimony. It has the same crystal structure as red phosphorus and black arsenic; it oxidizes in air and may ignite spontaneously. At 100 °C, it gradually transforms into the stable form. The yellow allotrope of antimony is the most unstable. It has only been generated by oxidation of stibine (SbH_3) at -90 °C. Above this temperature and in ambient light, this metastable allotrope transforms into the more stable black allotrope.

Metallic antimony adopts a layered structure (space group $R\bar{3}m$ No. 166) in which layers consist of fused ruffled six-membered rings. The nearest and next-nearest neighbors form a distorted octahedral complex, with the three atoms in the same double-layer being slightly closer than the three atoms in the next. This relatively close packing leads to a high density of 6.697 g/cm³, but the weak bonding between the layers leads to the low hardness and brittleness of antimony.

Isotopes

Antimony exists as two stable isotopes, ^{121}Sb with a natural abundance of 57.36% and ^{123}Sb with a natural abundance of 42.64%. It also has 35 radioisotopes, of which the longest-lived is ^{125}Sb with a half-life of 2.75 years. In addition, 29 metastable states have been characterized. The most stable of these is ^{124}Sb with a half-life of 60.20 days, which has an application in some neutron sources. Isotopes that are lighter than the stable ^{123}Sb tend to decay by β^+ decay, and those that are heavier tend to decay by β^- decay, with some exceptions.

Occurrence

The abundance of antimony in the Earth's crust is estimated at 0.2 to 0.5 parts per million, comparable to thallium at 0.5 parts per million and silver at 0.07 ppm. Even though this element is not abundant, it is found in over 100 mineral species. Antimony is sometimes found natively, but more frequently it is found in the sulfide stibnite (Sb_2S_3) which is the predominant ore mineral.

Antimony compounds are often classified into those of Sb(III) and Sb(V). Relative to its congener arsenic, the +5 oxidation state is more stable.

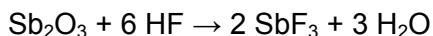
Oxides and hydroxides

Antimony trioxide (Sb_2O_3) is formed when antimony is burnt in air. In the gas phase, this compound exists as Sb_4O_6 , but it polymerizes upon condensing. Antimony pentoxide (Sb_2O_5) can only be formed by oxidation by concentrated nitric acid. Antimony also forms a mixed-valence oxide, antimony tetroxide (Sb_2O_4), which features both Sb(III) and Sb(V). Unlike phosphorus and arsenic, these various oxides are amphoteric, do not form well-defined oxoacids and react with acids to form antimony salts.

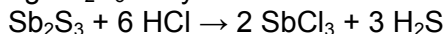
Antimonous acid $\text{Sb}(\text{OH})_3$ is unknown, but the conjugate base sodium antimonite ($[\text{Na}_3\text{SbO}_3]_4$) forms upon fusing sodium oxide and Sb_2O_3 . Transition metal antimonites are also known. Antimonic acid exists only as the hydrate $\text{HSb}(\text{OH})_6$, forming salts containing the antimonate anion $\text{Sb}(\text{OH})_6^-$. Dehydrating metal salts containing this anion yields mixed oxides. Many antimony ores are sulfides, including stibnite (Sb_2S_3), pyrargyrite (Ag_3SbS_3), zinkenite, jamesonite, and boulangerite. Antimony pentasulfide is non-stoichiometric and features antimony in the +3 oxidation state and S-S bonds. Several thioantimonides are known, such as $[\text{Sb}_6\text{S}_{10}]^{2-}$ and $[\text{Sb}_8\text{S}_{13}]^{2-}$.

Halides

Antimony forms two series of halides, SbX_3 and SbX_5 . The trihalides SbF_3 , SbCl_3 , SbBr_3 , and SbI_3 are all molecular compounds having trigonal pyramidal molecular geometry. The trifluoride SbF_3 is prepared by the reaction of Sb_2O_3 with HF:



It is Lewis acidic and readily accepts fluoride ions to form the complex anions SbF_4^- and SbF_6^- . Molten SbF_3 is a weak electrical conductor. The trichloride SbCl_3 is prepared by dissolving Sb_2S_3 in hydrochloric acid:

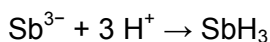


The pentahalides SbF_5 and SbCl_5 have trigonal bipyramidal molecular geometry in the gas phase, but in the liquid phase, SbF_5 is polymeric, whereas SbCl_5 is monomeric. SbF_5 is a powerful Lewis acid used to make the super acid fluoroantimonic acid (" HSbF_6 ").

Oxyhalides are more common for antimony than arsenic and phosphorus. Antimony trioxide dissolves in concentrated acid to form oxoantimonyl compounds such as SbOCl and $(\text{SbO})_2\text{SO}_4$.

Antimonides, hydrides, and organoantimony compounds

Compounds in this class generally are described as derivatives of Sb^{3-} . Antimony forms antimonides with metals, such as indium antimonide (InSb) and silver antimonide (Ag_3Sb). The alkali metal and zinc antimonides, such as Na_3Sb and Zn_3Sb_2 , are more reactive. Treating these antimonides with acid produces the unstable gas stibine, SbH_3 :



Stibine can also be produced by treating Sb^{3+} salts with hydride reagents such as sodium borohydride. Stibine decomposes spontaneously at room temperature. Because stibine has a positive heat of formation, it is thermodynamically unstable and thus antimony does not react with hydrogen directly.

Organoantimony compounds are typically prepared by alkylation of antimony halides with Grignard reagents. A large variety of compounds are known with both Sb(III) and Sb(V) centers, including mixed chloro-organic derivatives, anions, and cations. Examples include $\text{Sb}(\text{C}_6\text{H}_5)_3$ (triphenylstibine), $\text{Sb}_2(\text{C}_6\text{H}_5)_4$ (with an Sb-Sb bond), and cyclic $[\text{Sb}(\text{C}_6\text{H}_5)]_n$. Pentacoordinated organoantimony compounds are common, examples being $\text{Sb}(\text{C}_6\text{H}_5)_5$ and several related halides.

History

Antimony(III) sulfide, Sb_2S_3 , was recognized in predynastic Egypt as an eye cosmetic (kohl) as early as about 3100 BC, when the cosmetic palette was invented.

An artifact, said to be part of a vase, made of antimony dating to about 3000 BC was found at Telloh, Chaldea (part of present-day Iraq), and a copper object plated with antimony dating between 2500 BC and 2200 BC has been found in Egypt. Austen, at a lecture by Herbert Gladstone in 1892 commented that "we only know of antimony at the present day as a highly brittle and crystalline metal, which could hardly be fashioned into a useful vase, and therefore this remarkable 'find' (artifact mentioned above) must represent the lost art of rendering antimony malleable."

Moorey was unconvinced the artifact was indeed a vase, mentioning that Selimkhanov, after his analysis of the Tello object (published in 1975), "attempted to relate the metal to Transcaucasian natural antimony" (i.e. native metal) and that "the antimony objects from Transcaucasia are all small personal ornaments." This weakens the evidence for a lost art "of rendering antimony malleable."

The first European description of a procedure for isolating antimony is in the book *De la pirotechnia* of 1540 by Vannoccio Biringuccio; this predates the more famous 1556 book by Agricola, *De re metallica*. In this context Agricola has been often incorrectly credited with the discovery of metallic antimony. The book *Currus Triumphalis Antimonii* (The Triumphal Chariot of Antimony), describing the preparation of metallic antimony, was published in Germany in 1604. It was purported to have been written by a Benedictine monk, writing under the name Basilius Valentinus, in the 15th century; if it were authentic, which it is not, it would predate Biringuccio.

The first natural occurrence of pure antimony in the Earth's crust was described by the Swedish scientist and local mine district engineer Anton von Swab in 1783; the type-sample was collected from the Sala Silver Mine in the Bergslagen mining district of Sala, Västmanland, Sweden.

Arsenic- Inorganic Contaminant 0.010 mg/L Water MCL Metalloid

Arsenic is a chemical element with symbol **As** and the atomic number is 33. Arsenic occurs in many minerals, usually in conjunction with sulfur and metals, and also as a pure elemental crystal. It was first documented by Albertus Magnus in 1250. Arsenic is a metalloid. It can exist in various allotropes, although only the gray form has important use in industry.

In 1974, Congress passed the Safe Drinking Water Act. This law requires EPA to determine the level of contaminants in drinking water at which no adverse health effects are likely to occur. These non-enforceable health goals, based solely on possible health risks and exposure over a lifetime with an adequate margin of safety, are called maximum contaminant level goals (MCLG). Contaminants are any physical, chemical, biological or radiological substances or matter in water.



The MCLG for arsenic is zero. EPA has set this level of protection based on the best available science to prevent potential health problems. Based on the MCLG, EPA has set an enforceable regulation for arsenic, called a maximum contaminant level (MCL), at 0.010 mg/L or 10 ppb. MCLs are set as close to the health goals as possible, considering cost, benefits and the ability of public water systems to detect and remove contaminants using suitable treatment technologies.

The Arsenic and Clarifications to Compliance and New Source Contaminants Monitoring Final Rule, the regulation for arsenic, became effective in 2002. The Safe Drinking Water Act requires EPA to periodically review and revise contaminants, if appropriate, based on new scientific data. The regulation for arsenic will be included in a future review cycle.

The main uses of metallic arsenic is for strengthening alloys of copper and especially lead (for example, in car batteries). Arsenic is a common n-type dopant in semiconductor electronic devices, and the optoelectronic compound gallium arsenide is the most common semiconductor in use after doped silicon. Arsenic and its compounds, especially the trioxide, are used in the production of pesticides (treated wood products), herbicides, and insecticides. These applications are declining, however.

Arsenic is notoriously poisonous to multicellular life, although a few species of bacteria are able to use arsenic compounds as respiratory metabolites. Arsenic contamination of groundwater is a problem that affects millions of people across the world.

Arsenic, a naturally occurring element, is found throughout the environment; for most people, food is the major source of exposure. Acute (short-term) high-level inhalation exposure to arsenic dust or fumes has resulted in gastrointestinal effects (nausea, diarrhea, abdominal pain); central and peripheral nervous system disorders have occurred in workers acutely exposed to inorganic arsenic. Chronic (long-term) inhalation exposure to inorganic arsenic in humans is associated with irritation of the skin and mucous membranes. Chronic oral exposure has resulted in gastrointestinal effects, anemia, peripheral neuropathy, skin lesions, hyperpigmentation, and liver or kidney damage in humans. Inorganic arsenic exposure in humans, by the inhalation route, has been shown to be strongly associated with lung cancer, while ingestion of inorganic arsenic in humans has been linked to a form of skin cancer and also to bladder, liver, and lung cancer. EPA has classified inorganic arsenic as a Group A, human carcinogen.

Contamination of Groundwater

Arsenic contamination of groundwater is often due to naturally occurring high concentrations of arsenic in deeper levels of groundwater. It is a high-profile problem due to the use of deep tubewells for water supply in the Ganges Delta, causing serious arsenic poisoning to large numbers of people. In addition, mining techniques such as hydraulic fracturing mobilize arsenic in groundwater and aquifers due to enhanced methane transport and resulting changes in redox conditions, and inject fluid containing additional arsenic.

A 2007 study found that over 137 million people in more than 70 countries are probably affected by arsenic poisoning of drinking water. Arsenic contamination of ground water is found in many countries throughout the world, including the USA.

Approximately 20 incidents of groundwater arsenic contamination have been reported from all over the world. Of these, four major incidents were in Asia, including locations in Thailand, Taiwan, and Mainland China. In South America, Argentina and Chile are affected. There are also many locations in the United States where the groundwater contains arsenic concentrations in excess of the Environmental Protection Agency standard of 10 parts per billion adopted in 2001. Millions of private wells have unknown arsenic levels, and in some areas of the US, over 20% of wells may contain levels that are not safe.

Arsine

Arsine is a gas consisting of arsenic and hydrogen. It is extremely toxic to humans, with headaches, vomiting, and abdominal pains occurring within a few hours of exposure. EPA has not classified arsine for carcinogenicity.

Drinking water regulations require public water systems to monitor for arsenic at the entry point to the distribution system. There is no federal requirement for systems to monitor for arsenic within the distribution system. You may, however, want to test your distribution system water for arsenic to be sure that the water being delivered has arsenic levels below the MCL. If you decide to monitor your distribution system, consider testing for arsenic at locations where the settling and accumulation of iron solids or pipe scales are likely (i.e., areas with cast iron pipe, ductile iron pipe, or galvanized iron pipe).

If your water system has installed some form of arsenic treatment, keep in mind that the treatment you installed may change the water quality in other ways. It might cause the water to react differently in the distribution system. Depending on the kind of treatment you've installed, consider what distribution system problems might result.

A change in the taste, odor or appearance of the water at customers' taps may be the first indication of a problem. Some water quality parameters to consider monitoring, depending on your arsenic treatment technology, include iron, pH, manganese, alkalinity, and aluminum.

The current drinking water standard or Maximum Contaminant Level (MCL) set by the U.S. Environmental Protection Agency (EPA) is 0.010 mg/L or parts per million (ppm). This is equivalent to 10 ug/L (micrograms per liter) or 10 ppb. In 2001, the U.S. Environmental Protection Agency (EPA) reduced the regulatory MCL from 50 ppb to 10 ppb on the basis on bladder and lung cancer risks. The MCL is based on the average individual consuming 2 liters of water a day for a lifetime. Long term exposure to drinking water containing arsenic at levels higher than 10 ppb increases the chances of getting cancer, while for lower arsenic water levels the chances are less.

If your water has arsenic levels above 10 ppb, you should obtain drinking water from another source or install a home treatment device. Concentrations above 10 ppb will increase the risk of long-term or chronic health problems, the higher the level and length of exposure, the greater the risk. It is especially important to reduce arsenic water concentrations if you have children or are pregnant. Children are at greater risk (to any agent in water) because of their greater water consumption on a per unit body weight basis.

Pregnant women may wish to reduce their arsenic exposures because arsenic has been found at low levels in mother's milk and will cross the placenta, increasing exposures and risks for the fetus. If your water has arsenic levels above 200 ppb, you should immediately stop drinking the water until you can either obtain water from another source or install and maintain treatment.

Physical Characteristics

The three most common arsenic allotropes are *metallic gray*, *yellow* and *black arsenic*, with gray being the most common. *Gray arsenic* (α -As, space group R3m No. 166) adopts a double-layered structure consisting of many interlocked ruffled six-membered rings. Because of weak bonding between the layers, gray arsenic is brittle and has a relatively low Mohs hardness of 3.5. Nearest and next-nearest neighbors form a distorted octahedral complex, with the three atoms in the same double-layer being slightly closer than the three atoms in the next. This relatively close packing leads to a high density of 5.73 g/cm³. Gray arsenic is a semimetal, but becomes a semiconductor with a bandgap of 1.2–1.4 eV if amorphized. *Yellow arsenic* is soft and waxy, and somewhat similar to tetraphosphorus (P₄). Both have four atoms arranged in a tetrahedral structure in which each atom is bound to each of the other three atoms by a single bond. This unstable allotrope, being molecular, is the most volatile, least dense and most toxic. Solid yellow arsenic is produced by rapid cooling of arsenic vapor, As₄. It is rapidly transformed into the gray arsenic by light. The yellow form has a density of 1.97 g/cm³. *Black arsenic* is similar in structure to red phosphorus.

Isotopes

Naturally occurring arsenic is composed of one stable isotope, ⁷⁵As. As of 2003, at least 33 radioisotopes have also been synthesized, ranging in atomic mass from 60 to 92. The most stable of these is ⁷³As with a half-life of 80.3 days. Isotopes that are lighter than the stable ⁷⁵As tend to decay by β^+ decay, and those that are heavier tend to decay by β^- decay, with some exceptions.

At least 10 nuclear isomers have been described, ranging in atomic mass from 66 to 84. The most stable of arsenic's isomers is ^{68m}As with a half-life of 111 seconds.

Chemistry

When heated in air, arsenic oxidizes to arsenic trioxide; the fumes from this reaction have an odor resembling garlic. This odor can be detected on striking arsenide minerals such as arsenopyrite with a hammer. Arsenic (and some arsenic compounds) sublimes upon heating at atmospheric pressure, converting directly to a gaseous form without an intervening liquid state at 887 K (614 °C). The triple point is 3.63 MPa and 1,090 K (820 °C). Arsenic makes arsenic acid with concentrated nitric acid, arsenious acid with dilute nitric acid, and arsenic trioxide with concentrated sulfuric acid.

Compounds

Arsenic compounds resemble in some respects those of phosphorus, which occupies the same group (column) of the periodic table. Arsenic is less commonly observed in the pentavalent state, however. The most common oxidation states for arsenic are: -3 in the arsenides, such as alloy-like intermetallic compounds; and +3 in the arsenites, arsenates (III), and most organoarsenic compounds. Arsenic also bonds readily to itself as seen in the square As_3^- ions in the mineral skutterudite. In the +3 oxidation state, arsenic is typically pyramidal, owing to the influence of the lone pair of electrons.

Inorganic

Arsenic forms colorless, odorless, crystalline oxides As_2O_3 ("white arsenic") and As_2O_5 , which are hygroscopic and readily soluble in water to form acidic solutions. Arsenic (V) acid is a weak acid. Its salts are called arsenates, which is the basis of arsenic contamination of groundwater, a problem that affects many people. Synthetic arsenates include Paris Green (copper(II) acetoarsenite), calcium arsenate, and lead hydrogen arsenate. The latter three have been used as agricultural insecticides and poisons.

The protonation steps between the arsenate and arsenic acid are similar to those between phosphate and phosphoric acid. Unlike phosphorus acid, arsenous acid is genuinely tribasic, with the formula $\text{As}(\text{OH})_3$.

A broad variety of sulfur compounds of arsenic are known. Orpiment (As_2S_3) and realgar (As_4S_4) are somewhat abundant and were formerly used as painting pigments. In As_4S_{10} , arsenic has a formal oxidation state of +2 in As_4S_4 , which features As-As bonds so that the total covalency of As is still three.

The trifluoride, trichloride, tribromide, and triiodide of arsenic (III) are well known, whereas only Arsenic pentafluoride (AsF_5) is the only important pentahalide. Again reflecting the lower stability of the 5+ oxidation state, the pentachloride is stable only below -50 °C.

Organoarsenic Compounds

A large variety of organoarsenic compounds are known. Several were developed as chemical warfare agents during World War I, including vesicants such as lewisite and vomiting agents such as adamsite. Cacodylic acid, which is of historic and practical interest, arises from the methylation of arsenic trioxide, a reaction that has no analogy in phosphorus chemistry.

Alloys

Arsenic is used as the group 5 element in the III-V semiconductors gallium arsenide, indium arsenide, and aluminum arsenide. The valence electron count of GaAs is the same as a pair of Si atoms, but the band structure is completely different, which results in distinct bulk properties. Other arsenic alloys include the II-IV semiconductor cadmium arsenide.

Occurrence and Production

Minerals with the formula $MAsS$ and MAs_2 ($M = Fe, Ni, Co$) are the dominant commercial sources of arsenic, together with realgar (an arsenic sulfide mineral) and native arsenic. An illustrative mineral is arsenopyrite ($FeAsS$), which is structurally related to iron pyrite. Many minor As-containing minerals are known. Arsenic also occurs in various organic forms in the environment. Inorganic arsenic and its compounds, upon entering the food chain, are progressively metabolized to a less toxic form of arsenic through a process of methylation.

Other naturally occurring pathways of exposure include volcanic ash, weathering of arsenic-containing minerals and ores, and dissolved in groundwater. It is also found in food, water, soil, and air. Arsenic is absorbed by all plants, but is more concentrated in leafy vegetables, rice, apple and grape juice, and seafood. An additional route of exposure is through inhalation.

In 2005, China was the top producer of white arsenic with almost 50% world share, followed by Chile, Peru, and Morocco, according to the British Geological Survey and the United States Geological Survey. Most operations in the US and Europe have closed for environmental reasons. The arsenic is recovered mainly as a side product from the purification of copper. Arsenic is part of the smelter dust from copper, gold, and lead smelters.

On roasting in air of arsenopyrite, arsenic sublimes as arsenic (III) oxide leaving iron oxides, while roasting without air results in the production of metallic arsenic. Further purification from sulfur and other chalcogens is achieved by sublimation in vacuum or in a hydrogen atmosphere or by distillation from molten lead-arsenic mixture.

Health Hazard Information

Arsenic

Arsenic is known to cause cancer, as well as many other serious health problems. Here we review the hazards of arsenic exposure and ways people can protect themselves from these hazards.

Arsenic is an element in the environment that can be found naturally in rocks and soil, water, air, and in plants and animals. It can also be released into the environment from some agricultural and industrial sources.

Arsenic has no taste or smell. Although sometimes found in its pure form as a steel grey metal, arsenic is usually part of chemical compounds. These compounds are divided into 2 groups:

- Inorganic compounds (combined with oxygen, iron, chlorine, and sulfur)
- Organic compounds (combined with carbon and other atoms)

Inorganic arsenic compounds are found in industry, in building products (in some "pressure-treated" woods), and in arsenic-contaminated water. This is the form of arsenic that tends to be more toxic and has been linked to cancer.

Organic arsenic compounds are much less toxic than the inorganic arsenic compounds and are not thought to be linked to cancer. These compounds are found in some foods, such as fish and shellfish.

While arsenic levels may fluctuate over time, what is most significant from the standpoint of cancer risk is long-term exposure.

For water systems in the 25 states that reported arsenic data to the EPA, we have calculated two estimates of average long-term levels: one is a very conservative estimate, the other our best estimate, based on what we believe to be the most reasonable analytical techniques (details on how we arrived at the estimates are included with the charts).

The table below shows the lifetime risks of dying of cancer from arsenic in tap water, based on the National Academy of Sciences' 1999 risk estimates.

Arsenic Level in Tap Water (in parts per billion, or ppb)	Approximate Total Cancer Risk (assuming 2 liters consumed/day)
0.5 ppb	1 in 10,000
1 ppb	1 in 5,000
3 ppb	1 in 1,667
4 ppb	1 in 1,250
5 ppb	1 in 1,000
10 ppb	1 in 500
20 ppb	1 in 250
25 ppb	1 in 200
50 ppb	1 in 100

Arsenic Diabetes

New research findings from the National Health and Nutrition Examination Survey suggest that exposure to levels of arsenic commonly found in drinking water may be a risk factor for type 2 diabetes. The findings suggest that millions of Americans may be at increased risk for type 2 diabetes based on the level of arsenic in their drinking water.

Data on the nearly 800 participants in the study for which urinary arsenic concentrations were available, indicated that urine levels of arsenic were significantly associated with the prevalence of type 2 diabetes. After splitting the subjects into 5 groups based on the level of arsenic in their urine, the researchers determined that those in the highest category were more than three and one-half times more likely to have diabetes. The strength of arsenic as a risk factor for diabetes is similar to other factors such as obesity.

Inorganic arsenic in drinking water at concentrations higher than 100 parts per million has been linked to type 2 diabetes in studies that took place in Taiwan, Mexico, and Bangladesh where drinking water is commonly contaminated with high levels of arsenic. The US drinking water standard is currently 10 parts per million, but most people on private wells have not had their water tested and aren't required to. The researchers estimate that about 13 million Americans live in areas where public water systems exceed the EPA standard for arsenic and this number does not include private wells and water systems.

Animal studies have shown that arsenic affects the production of glucose, insulin secretion and can cause insulin resistance. The current findings reinforce the need to evaluate the role of arsenic in diabetes development in prospective epidemiologic studies conducted in populations exposed to a wide range of arsenic levels.

Acute Effects:**Inorganic Arsenic**

- Acute inhalation exposure of workers to high levels of arsenic dusts or fumes has resulted in gastrointestinal effects (nausea, diarrhea, abdominal pain), while acute exposure of workers to inorganic arsenic has also resulted in central and peripheral nervous system disorders.
- Acute oral exposure to inorganic arsenic, at doses of approximately 600 micrograms per kilogram body weight per day ($\mu\text{g/kg/d}$) or higher in humans, has resulted in death. Oral exposure to lower levels of inorganic arsenic has resulted in effects on the gastrointestinal tract (nausea, vomiting), central nervous system (CNS) (headaches, weakness, delirium), cardiovascular system (hypotension, shock), liver, kidney, and blood (anemia, leukopenia).
- Acute animal tests in rats and mice have shown inorganic arsenic to have moderate to high acute toxicity.

Arsine

- Acute inhalation exposure to arsine by humans has resulted in death; it has been reported that a half-hour exposure to 25 to 50 parts per million (ppm) can be lethal.
- The major effects from acute arsine exposure in humans include headaches, vomiting, abdominal pains, hemolytic anemia, hemoglobinuria, and jaundice; these effects can lead to kidney failure.
- Arsine has been shown to have extreme acute toxicity from acute animal tests.

Chronic Effects (Non-cancer):**Inorganic arsenic**

- Chronic inhalation exposure to inorganic arsenic in humans is associated with irritation of the skin and mucous membranes (dermatitis, conjunctivitis, pharyngitis, and rhinitis).
- Chronic oral exposure to inorganic arsenic in humans has resulted in gastrointestinal effects, anemia, peripheral neuropathy, skin lesions, hyperpigmentation, gangrene of the extremities, vascular lesions, and liver or kidney damage.
- No chronic inhalation exposure studies have been performed in animals for any inorganic arsenic compound.
- Some studies have suggested that inorganic arsenic is an essential dietary nutrient in goats, chicks, and rats. However, no comparable data are available for humans. EPA has concluded that essentiality, although not rigorously established, is plausible.



- EPA has not established a Reference Concentration (RfC) for inorganic arsenic.
- The California Environmental Protection Agency (CalEPA) has established a chronic inhalation reference level of 0.00003 milligrams per cubic meter (mg/m³) based on developmental effects in mice. The CalEPA reference exposure level is a concentration at or below which adverse health effects are not likely to occur. It is not a direct estimator of risk, but rather a reference point to gauge the potential effects. At lifetime exposures increasingly greater than the reference exposure level, the potential for adverse health effects increases.
- The Reference Dose (RfD) for inorganic arsenic is 0.0003 milligrams per kilogram body weight per day (mg/kg/d) based on hyperpigmentation, keratosis, and possible vascular complications in humans. The RfD is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily oral exposure to the human population (including sensitive subgroups) that is likely to be without appreciable risk of deleterious noncancer effects during a lifetime.
- EPA has medium confidence in the study on which the RfD for inorganic arsenic was based because, although an extremely large number of people were included in the assessment (>40,000), the doses were not well characterized and other contaminants were present. The supporting human toxicity database, while extensive, is somewhat flawed and, consequently, EPA has assigned medium confidence to the RfD.

Arsine

- No information is available on the chronic effects of arsine in humans.
- The RfC for arsine is 0.00005 mg/m³ based on increased hemolysis, abnormal red blood cell morphology, and increased spleen weight in rats, mice, and hamsters.
- EPA has medium confidence in the RfC based on: (1) high confidence in the studies on which the RfC for arsine was based because the sample sizes were adequate, statistical significance was reported, concentration dose-response relationships were documented, three species were investigated, and both a no-observed-adverse-effect level (NOAEL) and a lowest-observed-adverse-effect level (LOAEL) were identified, and (2) medium confidence in the database because while there were three inhalation animal studies and a developmental/reproductive study, there were no data available on human exposure.

Reproductive/Developmental Effects: **Inorganic arsenic**

- Several studies have suggested that women who work in, or live near, metal smelters may have higher than normal spontaneous abortion rates, and their children may exhibit lower than normal birth weights. However, these studies are limited because they were designed to evaluate the effects of smelter pollutants in general, and are not specific for inorganic arsenic.
- Ingested inorganic arsenic can cross the placenta in humans, exposing the fetus to the chemical.
- Oral animal studies have reported inorganic arsenic at very high doses to be fetotoxic and to cause birth defects.

Arsine

- Human studies have indicated higher than expected spontaneous abortion rates in women in the microelectronics industry who were exposed to arsine. However, these studies have several limitations, including small sample size and exposure to other chemicals in addition to arsine.

Cancer Risk:

Inorganic arsenic

- Human, inhalation studies have reported inorganic arsenic exposure to be strongly associated with lung cancer.
- Ingestion of inorganic arsenic in humans has been associated with an increased risk of nonmelanoma skin cancer and also to an increased risk of bladder, liver, and lung cancer.
- Animal studies have not associated inorganic arsenic exposure via the oral route with cancer, and no cancer inhalation studies have been performed in animals for inorganic arsenic.
- EPA has classified inorganic arsenic as a Group A, human carcinogen.
- EPA used a mathematical model, using data from an occupational study of arsenic-exposed copper smelter workers, to estimate the probability of a person developing cancer from continuously breathing air containing a specified concentration of inorganic arsenic. EPA calculated an inhalation unit risk estimate of $4.3 \times 10^{-3}(\mu\text{g}/\text{m}^3)^{-1}$. EPA estimates that, if an individual were to continuously breathe air containing inorganic arsenic at an average of $0.0002 \mu\text{g}/\text{m}^3$ ($2 \times 10^{-7} \text{ mg}/\text{m}^3$) over his or her entire lifetime, that person would theoretically have no more than a one-in-a-million increased chance of developing cancer as a direct result of breathing air containing this chemical. Similarly, EPA estimates that continuously breathing air containing $0.002 \mu\text{g}/\text{m}^3$ ($2 \times 10^{-6} \text{ mg}/\text{m}^3$) would result in not greater than a one-in-a-hundred thousand increased chance of developing cancer, and air containing $0.02 \mu\text{g}/\text{m}^3$ ($2 \times 10^{-5} \text{ mg}/\text{m}^3$) would result in not greater than a one-in-ten thousand increased chance of developing cancer. For a detailed discussion of confidence in the potency estimates, please see IRIS.
- EPA has calculated an oral cancer slope factor of $1.5 (\text{mg}/\text{kg}/\text{d})^{-1}$ for inorganic arsenic.

Arsine

- No cancer inhalation studies in humans or animals are available for arsine.
- EPA has not classified arsine for carcinogenicity.

Physical Properties

- Inorganic arsenic is a naturally occurring element in the earth's crust.
- Pure inorganic arsenic is a gray-colored metal, but inorganic arsenic is usually found combined with other elements such as oxygen, chlorine, and sulfur.
- The chemical symbol for inorganic arsenic is As, and it has an atomic weight of 74.92 g/mol.

- The chemical formula for arsine is AsH_3 , and it has a molecular weight of 77.95 g/mol.
- Arsine is a colorless gas with a disagreeable garlic odor.
- Arsenic combined with elements such as oxygen, chlorine, and sulfur forms inorganic arsenic; inorganic arsenic compounds include arsenic pentoxide, arsenic trioxide, and arsenic acid. Arsenic combined with carbon and hydrogen forms organic arsenic; organic arsenic compounds include arsanilic acid, arsenobetaine, and dimethylarsinic acid.

History

The word "Arsenic" was adopted in Latin *arsenicum* and Old French *arsenic*, from which the English word *arsenic* is derived. Arsenic sulfides (orpiment, realgar) and oxides have been known and used since ancient times. Zosimos (circa 300 AD) describes roasting *sandarach* (realgar) to obtain *cloud of arsenic* (arsenious oxide), which he then reduces to metallic arsenic. As the symptoms of arsenic poisoning were somewhat ill-defined, it was frequently used for murder until the advent of the Marsh test, a sensitive chemical test for its presence. (Another less sensitive but more general test is the Reinsch test.) Owing to its use by the ruling class to murder one another and its potency and discreetness, arsenic has been called the *Poison of Kings* and the *King of Poisons*.

During the Bronze Age, arsenic was often included in bronze, which made the alloy harder (so-called "arsenical bronze"). Albertus Magnus (Albert the Great, 1193–1280) is believed to have been the first to isolate the element from a compound in 1250, by heating soap together with arsenic trisulfide. In 1649, Johann Schröder published two ways of preparing arsenic. Crystals of elemental (native) arsenic are found in nature, although rare. Cadet's fuming liquid (impure cacodyl), often claimed as the first synthetic organometallic compound, was synthesized in 1760 by Louis Claude Cadet de Gassicourt by the reaction of potassium acetate with arsenic trioxide.

In the Victorian era, "arsenic" ("white arsenic" or arsenic trioxide) was mixed with vinegar and chalk and eaten by women to improve the complexion of their faces, making their skin paler to show they did not work in the fields. Arsenic was also rubbed into the faces and arms of women to "improve their complexion". The accidental use of arsenic in the adulteration of foodstuffs led to the Bradford sweet poisoning in 1858, which resulted in approximately 20 deaths.

Arsenic Applications

Agricultural

The toxicity of arsenic to insects, bacteria and fungi led to its use as a wood preservative. In the 1950s a process of treating wood with chromated copper arsenate (also known as CCA or Tanalith) was invented, and for decades this treatment was the most extensive industrial use of arsenic. An increased appreciation of the toxicity of arsenic resulted in a ban for the use of CCA in consumer products; the European Union and United States initiated this process in 2004. CCA remains in heavy use in other countries however, e.g. Malaysian rubber plantations.

Arsenic was also used in various agricultural insecticides, termination and poisons. For example, lead hydrogen arsenate was a common insecticide on fruit trees, but contact with the compound sometimes resulted in brain damage among those working the sprayers. In the second half of the 20th century, monosodium methyl arsenate (MSMA) and disodium methyl arsenate (DSMA) – less toxic organic forms of arsenic – have replaced lead arsenate in agriculture.

Arsenic is still added to animal food, in particular in the US as a method of disease prevention and growth stimulation. One example is roxarsone, which is used as a broiler starter by about 70% of the broiler growers since 1995. The Poison-Free Poultry Act of 2009 proposes to ban the use of roxarsone in industrial swine and poultry production. Alpharma, a subsidiary of Pfizer Inc., which produces Roxarsone, has voluntarily suspended sales of the drug in response to studies showing elevated levels of arsenic in treated chickens.

Medical use

During the 18th, 19th, and 20th centuries, a number of arsenic compounds have been used as medicines, including arsphenamine (by Paul Ehrlich) and arsenic trioxide (by Thomas Fowler). Arsphenamine as well as neosalvarsan was indicated for syphilis and trypanosomiasis, but has been superseded by modern antibiotics. Arsenic trioxide has been used in a variety of ways over the past 500 years, but most commonly in the treatment of cancer. The US Food and Drug Administration in 2000 approved this compound for the treatment of patients with acute promyelocytic leukemia that is resistant to ATRA.

It was also used as Fowler's solution in psoriasis. Recently new research has been done in locating tumors using arsenic-74 (a positron emitter). The advantages of using this isotope instead of the previously used iodine-124 is that the signal in the PET scan is clearer as the body tends to transport iodine to the thyroid gland producing a lot of noise. In subtoxic doses, soluble arsenic compounds act as stimulants, and were once popular in small doses as medicine by people in the mid-18th century.

Alloys

The main use of metallic arsenic is for alloying with lead. Lead components in car batteries are strengthened by the presence of a few percent of arsenic. Dezincification can be strongly reduced by adding arsenic to brass, a copper-zinc alloy. Gallium arsenide is an important semiconductor material, used in integrated circuits. Circuits made from GaAs are much faster (but also much more expensive) than those made in silicon. Unlike silicon it has a direct bandgap, and so can be used in laser diodes and LEDs to directly convert electricity into light.

Military

After World War I, the United States built up a stockpile of 20,000 tons of lewisite ($\text{ClCH}=\text{CHAsCl}_2$), a chemical weapon that is a vesicant (blister agent) and lung irritant. The stockpile was neutralized with bleach and dumped into the Gulf of Mexico after the 1950s. During the Vietnam War the United States used Agent Blue, a mixture of sodium cacodylate and its acid form, as one of the rainbow herbicides to deprive invading North Vietnamese soldiers of foliage cover and rice.

Other uses

- Copper acetoarsenite was used as a green pigment known under many names, including 'Paris Green' and 'Emerald Green'. It caused numerous arsenic poisonings. Scheele's Green, a copper arsenate, was used in the 19th century as a coloring agent in sweets.
- Also used in bronzing and pyrotechnics.
- Up to 2% of arsenic is used in lead alloys for lead shots and bullets.
- Arsenic is added in small quantities to alpha-brass to make it dezincification resistant. This grade of brass is used to make plumbing fittings or other items that are in constant contact with water.
- Arsenic is also used for taxonomic sample preservation.
- Until recently arsenic was used in optical glass. Modern glass manufacturers, under pressure from environmentalists, have removed it, along with lead.

Bacteria

Some species of bacteria obtain their energy by oxidizing various fuels while reducing arsenate to arsenite. Under oxidative environmental conditions some bacteria use arsenite, which is oxidized to arsenate as fuel for their metabolism. The enzymes involved are known as arsenate reductases (Arr).

In 2008, bacteria were discovered that employ a version of photosynthesis in the absence of oxygen with arsenites as electron donors, producing arsenates (just as ordinary photosynthesis uses water as electron donor, producing molecular oxygen). Researchers conjecture that, over the course of history, these photosynthesizing organisms produced the arsenates that allowed the arsenate-reducing bacteria to thrive. One strain PHS-1 has been isolated and is related to the Gammaproteobacterium *Ectothiorhodospira shaposhnikovii*. The mechanism is unknown, but an encoded Arr enzyme may function in reverse to its known homologues. Although the arsenate and phosphate anions are similar structurally, no evidence exists for the replacement of phosphate in ATP or nucleic acids by arsenic.

It is known that even if your water has detectable levels of arsenic that are below the 0.010 mg/L MCL, and you have iron pipes or components in your distribution system, your system's pipes may have arsenic-rich scales attached to them. As long as the scales are not disturbed, they will remain attached to the pipes or other distribution system components. Certain conditions, such as flushing of mains or fire flow conditions, may result in those scales being sloughed off and suspended in the water, releasing the arsenic. Other conditions, such as changes in water chemistry, may result in some of the arsenic dissolving back into the water. Both of these situations could cause high arsenic levels at consumers' taps.

Arsenic Control Measures Can Affect Finished Water Quality

Public water systems installing arsenic treatment should be informed about possible changes to their finished water that may result from the arsenic treatment they install. For example, systems may need to adjust their finished water quality to address new concerns about corrosion. Changes in water chemistry due to using new sources, blending different source waters, or installing arsenic treatment are some of the factors that can affect distribution system water quality. In some cases, this may cause an increase in arsenic levels in the distribution system or create simultaneous compliance issues with other drinking water regulations.

Water systems may also find deposits of arsenic-rich particles in their storage tanks or at locations in their distribution system with low flows. If the flow is increased or a storage tank is drawn down to a low level, these arsenic-rich particles can get stirred up and transported to consumers' taps. This situation occurs primarily when iron media used in treatment are released into the distribution system, or when iron particles are not properly filtered out during iron removal treatment. If these treatment technologies are operated correctly, this should not be a problem for most water systems.

Is Arsenic in your Storage Tank?

Is Your Ground Water System Installing Disinfection for Pathogen Control?

Water systems that disinfect their water should be aware of the possibility of an increase in arsenic concentrations in their distribution system, particularly if the water contains high concentrations of dissolved iron. When chlorinated, the dissolved iron forms particles on which arsenic can accumulate. As a result, high arsenic concentrations may occur in distribution system water even if arsenic concentrations in the raw water are below the MCL.

This happened to a small community water system in the Midwest that began chlorinating water from a series of wells that had raw water arsenic levels between 0.003 and 0.008 mg/L and iron concentrations up to 0.4 mg/L. At the same time, the system installed a polyphosphate feed system for corrosion control. Soon after chlorination began, the system received intermittent colored-water complaints from its customers with increasing frequency across the distribution system.

Samples collected from several representative locations throughout the service area had a reddish-brown color and contained particles. A metals analysis showed high levels of copper and iron oxides in the finished water, along with arsenic concentrations approaching 5 mg/L. Because of the water's colored appearance, it was considered unlikely that customers would consume the water. Doctors and health care professionals were notified of the situation and instructed to watch for signs of arsenic poisoning.

Researchers found that chlorinating the water caused the formation of ferri-hydroxide solids. The minimal arsenic present in the groundwater was being concentrated as it absorbed onto the solids. Copper oxide particulates also formed and were released. To some extent, the polyphosphates served a useful role by keeping iron in solution and counteracting the tendency for the iron oxides to form, but additional steps were needed. For six months the system alternated their chlorination schedule: on for one day then off two days. The system then returned to full-time chlorination, starting with a low distribution system residual of 0.2 mg/L and gradually increasing it to 0.5 mg/L. The system continued to flush water mains on a semi-annual schedule using a unidirectional approach. In the last year, the system received only one colored water complaint.

Heredity

Arsenic has been linked to epigenetic changes, heritable changes in gene expression that occur without changes in DNA sequence. These include DNA methylation, histone modification, and RNA interference. Toxic levels of arsenic cause significant DNA hypermethylation of tumor suppressor genes p16 and p53, thus increasing risk of carcinogenesis. These epigenetic events have been studied *in vitro* using human kidney cells and *in vivo* using rat liver cells and peripheral blood leukocytes in humans. Inductive coupled plasma mass spectrometry (ICP-MS) is used to detect precise levels of intracellular arsenic and its other bases involved in epigenetic modification of DNA. Studies investigating arsenic as an epigenetic factor will help in developing precise biomarkers of exposure and susceptibility.

The Chinese brake fern (*Pteris vittata*) hyperaccumulates arsenic present in the soil into its leaves and has a proposed use in phytoremediation.

Biomethylation

Inorganic arsenic and its compounds, upon entering the food chain, are progressively metabolized through a process of methylation. For example, the mold *Scopulariopsis brevicaulis* produce significant amounts of trimethylarsine if inorganic arsenic is present. The organic compound arsenobetaine is found in some marine foods such as fish and algae, and also in mushrooms in larger concentrations. The average person's intake is about 10–50 µg/day. Values about 1000 µg are not unusual following consumption of fish or mushrooms, but there is little danger in eating fish because this arsenic compound is nearly non-toxic.

Arsenic Environmental Issues

Arsenic Control Measures Can Affect Finished Water Quality

Public water systems installing arsenic treatment should be informed about possible changes to their finished water that may result from the arsenic treatment they install. For example, systems may need to adjust their finished water quality to address new concerns about corrosion. Changes in water chemistry due to using new sources, blending different source waters, or installing arsenic treatment are some of the factors that can affect distribution system water quality. In some cases, this may cause an increase in arsenic levels in the distribution system or create simultaneous compliance issues with other drinking water regulations.

Occurrence in drinking water

Widespread arsenic contamination of groundwater has led to a massive epidemic of arsenic poisoning in Bangladesh and neighboring countries. It is estimated that approximately 57 million people in the Bengal basin are drinking groundwater with arsenic concentrations elevated above the World Health Organization's standard of 10 parts per billion (ppb). However, a study of cancer rates in Taiwan suggested that significant increases in cancer mortality appear only at levels above 150 ppb.

The arsenic in the groundwater is of natural origin, and is released from the sediment into the groundwater, owing to the anoxic conditions of the subsurface. This groundwater began to be used after local and western NGOs and the Bangladeshi government undertook a massive shallow tube well drinking-water program in the late twentieth century. This program was designed to prevent drinking of bacteria-contaminated surface waters, but failed to test for arsenic in the groundwater. Many other countries and districts in Southeast Asia, such as Vietnam and Cambodia have geological environments conducive to generation of high-arsenic groundwaters. Arsenicosis was reported in Nakhon Si Thammarat, Thailand in 1987, and the dissolved arsenic in the Chao Phraya River is suspected of containing high levels of naturally occurring arsenic, but has not been a public health problem owing to the use of bottled water.

In the United States, arsenic is most commonly found in the ground waters of the southwest. Parts of New England, Michigan, Wisconsin, Minnesota and the Dakotas are also known to have significant concentrations of arsenic in ground water. Increased levels of skin cancer have been associated with arsenic exposure in Wisconsin, even at levels below the 10 part per billion drinking water standard, although this link has not been proven. According to a recent film funded by the US Superfund, millions of private wells have unknown arsenic levels, and in some areas of the US, over 20% of wells may contain levels that exceed established limits.

Low-level exposure to arsenic at concentrations found commonly in US drinking water compromises the initial immune response to H1N1 or swine flu infection according to NIEHS-supported scientists. The study, conducted in laboratory mice, suggests that people exposed to arsenic in their drinking water may be at increased risk for more serious illness or death in response to infection from the virus.

Some Canadians are drinking water that contains inorganic arsenic. Private dug well waters are most at risk for containing inorganic arsenic. Preliminary well water analyses typically does not test for arsenic. Researchers at the Geological Survey of Canada have modeled relative variation in natural arsenic hazard potential for the province of New Brunswick. This study has important implications for potable water and health concerns relating to inorganic arsenic.

Epidemiological evidence from Chile shows a dose-dependent connection between chronic arsenic exposure and various forms of cancer, in particular when other risk factors, such as cigarette smoking, are present. These effects have been demonstrated to persist below 50 ppb. Analyzing multiple epidemiological studies on inorganic arsenic exposure suggests a small but measurable risk increase for bladder cancer at 10 ppb. According to Peter Ravenscroft of the Department of Geography at the University of Cambridge, roughly 80 million people worldwide consume between 10 and 50 ppb arsenic in their drinking water. If they all consumed exactly 10 ppb arsenic in their drinking water, the previously cited multiple epidemiological study analysis would predict an additional 2,000 cases of bladder cancer alone. This represents a clear underestimate of the overall impact, since it does not include lung or skin cancer, and explicitly underestimates the exposure. Those exposed to levels of arsenic above the current WHO standard should weigh the costs and benefits of arsenic remediation.

Early (1973) evaluations of the removal of dissolved arsenic by drinking water treatment processes demonstrated that arsenic is very effectively removed by co-precipitation with either iron or aluminum oxides. The use of iron as a coagulant, in particular, was found to remove arsenic with efficiencies exceeding 90%. Several adsorptive media systems have been approved for point-of-service use in a study funded by the United States Environmental Protection Agency (US EPA) and the National Science Foundation (NSF).

A team of European and Indian scientists and engineers have set up six arsenic treatment plants in West Bengal based on in-situ remediation method (SAR Technology). This technology does not use any chemicals and arsenic is left as an insoluble form (+5 state) in the subterranean zone by recharging aerated water into the aquifer and thus developing an oxidation zone to support arsenic oxidizing micro-organisms. This process does not produce any waste stream or sludge and is relatively cheap.

Another effective and inexpensive method to remove arsenic from contaminated well water is to sink wells 500 feet or deeper to reach purer waters. A recent 2011 study funded by the US National Institute of Environmental Health Sciences' Superfund Research Program shows that deep sediments can remove arsenic and take it out of circulation.

Through this process called adsorption in which arsenic sticks to the surfaces of deep sediment articles, arsenic can be naturally removed from well water.

Magnetic separations of arsenic at very low magnetic field gradients have been demonstrated in point-of-use water purification with high-surface-area and monodisperse magnetite (Fe_3O_4) nanocrystals. Using the high specific surface area of Fe_3O_4 nanocrystals the mass of waste associated with arsenic removal from water has been dramatically reduced.

Epidemiological studies have suggested a correlation between chronic consumption of drinking water contaminated with arsenic and the incidence of all leading causes of mortality. The literature provides reason to believe arsenic exposure is causative in the pathogenesis of diabetes.

Hungarian engineer László Schremmer has recently discovered that by the use of chaff-based filters it is possible to reduce the arsenic content of water to 3 $\mu\text{g/L}$. This is especially important in areas where the potable water is provided by filtering the water extracted from the underground aquifer.

Wood Preservation in the US

As of 2002, US-based industries consumed 19,600 metric tons of arsenic. Ninety percent of this was used for treatment of wood with chromated copper arsenate (CCA). In 2007, 50% of the 5,280 metric tons of consumption was still used for this purpose. In the United States, the use of arsenic in consumer products was discontinued for residential and general consumer construction on December 31, 2003 and alternative chemicals are now used, such as Alkaline Copper Quaternary, borates, copper azole, cyproconazole, and propiconazole.

Although discontinued, this application is also one of the most concerns to the general public. The vast majority of older pressure-treated wood was treated with CCA. CCA lumber is still in widespread use in many countries, and was heavily used during the latter half of the 20th century as a structural and outdoor building material. Although the use of CCA lumber was banned in many areas after studies showed that arsenic could leach out of the wood into the surrounding soil (from playground equipment, for instance), a risk is also presented by the burning of older CCA timber. The direct or indirect ingestion of wood ash from burnt CCA lumber has caused fatalities in animals and serious poisonings in humans; the lethal human dose is approximately 20 grams of ash. Scrap CCA lumber from construction and demolition sites may be inadvertently used in commercial and domestic fires. Protocols for safe disposal of CCA lumber do not exist evenly throughout the world; there is also concern in some quarters about the widespread landfill disposal of such timber.

Asbestos - Inorganic Contaminant 7 Water MFL

In 1974, Congress passed the Safe Drinking Water Act. This law requires EPA to determine the level of contaminants in drinking water at which no adverse health effects are likely to occur. These non-enforceable health goals, based solely on possible health risks and exposure over a lifetime with an adequate margin of safety, are called maximum contaminant level goals (MCLG). Contaminants are any physical, chemical, biological or radiological substances or matter in water.

The MCLG for asbestos is 7 MFL. EPA has set this level of protection based on the best available science to prevent potential health problems. EPA has set an enforceable regulation for asbestos, called a maximum contaminant level (MCL), at 7 MFL. MCLs are set as close to the health goals as possible, considering cost, benefits and the ability of public water systems to detect and remove contaminants using suitable treatment technologies. In this case, the MCL equals the MCLG, because analytical methods or treatment technology do not pose any limitation.

The Phase II Rule, the regulation for asbestos, became effective in 1992. The Safe Drinking Water Act requires EPA to periodically review the national primary drinking water regulation for each contaminant and revise the regulation, if appropriate. EPA reviewed asbestos as part of the Six Year Review and determined that the 7 MFL MCLG and 7 MFL MCL for asbestos are still protective of human health.

How does Asbestos get into my Drinking Water?

The major sources of asbestos in drinking water are decay of asbestos cement water mains; and erosion of natural deposits.

A federal law called the Emergency Planning and Community Right to Know Act (EPCRA) requires facilities in certain industries, which manufacture, process, or use significant amounts of toxic chemicals, to report annually on their releases of these chemicals. For more information on the uses and releases of chemicals in your state, contact the Community Right-to-Know Hotline: (800) 424-9346.

How will I know if Asbestos is in my Drinking Water?

When routine monitoring indicates that asbestos levels are above the MCL, your water supplier must take steps to reduce the amount of asbestos so that it is below that level. Water suppliers must notify their customers as soon as practical, but no later than 30 days after the system learns of the violation. Additional actions, such as providing alternative drinking water supplies, may be required to prevent serious risks to public health.

How will Asbestos be removed from my Drinking Water?

The following treatment method(s) have proven to be effective for removing asbestos to below 7 MFL: coagulation/filtration, direct and diatomite filtration, and corrosion control.



Asbestos Cement Pipe (ACP)

Common water distribution pipe, notice that both pipes have been cut with a power saw. You are not allowed to cut this type of pipe with a power saw, because it will spread the Asbestos.

Wetting agents may be applied with garden sprayers or hoses. Garden sprayers are hand-held, portable, and have a one- to five-gallon capacity. Water hoses are usually attached to a faucet tap, fire hydrant or water tank. Generally, the hose has a nozzle attached which spreads the water stream so that a fine mist is created.

Asbestos-Cement Products

Asbestos-cement products (such as transite) are commonly used for duct insulation, pipes, and siding. Being a Category II nonfriable ACM, asbestos-cement products need to be removed prior to demolition if they have a high probability of becoming crumbled, pulverized, or reduced to powder during demolition activities. EPA believes that most demolition activities will subject such Category II nonfriable ACM to the regulation.

Asbestos is an Excellent ...

Heat Stability

Asbestos will maintain its structural integrity at temperatures well above 800 F. The melting point is at about 2800 F

Thermal Insulation

The fibers have a relatively large surface area, along with numerous pores, and cracks. This allows for a low heat transfer. This makes it useful as an insulator in homes and machinery. The large surface area also absorbs water making it practical as pipe insulator to prevent sweating.

Chemical Resistance

The amphiboles are resistant to aqueous media and chemical attack. They also show high resistance to acids. This makes this class of asbestos useful for battery packing. Chrysotile is significantly less resistant to chemical destruction.

Sound Absorption

Asbestos have a large internal volume, large surface area, and the fibers are flexible. This makes it ideal for the absorption of sound energy. It is often used to help acoustics.



Serpent

Asbestos

OSHA requires that employees who may be exposed to dangerous levels of asbestos must be made aware of the hazards and how to protect themselves. Employees must be told where in their workplace they can find copies of all applicable asbestos standards. Employers must provide any employee with the opportunity to review the regulations if they so desire. It is an employee's right to have access to the regulations.

What Is Asbestos?

Asbestos is the name given to a number of naturally occurring fibrous silicate minerals that have been mined for their useful properties such as thermal insulation, chemical and thermal stability, and high tensile strength. The three most common types of asbestos are: a) chrysotile, b) amosite and c) crocidolite. Chrysotile, also known as white asbestos and a member of the Serpentine mineral group is the commonest. Asbestos can only be identified under a microscope.



Asbestos differs from other minerals in its crystal development. The crystal formation of asbestos is in the form of long thin fibers. Asbestos is divided into two mineral groups

Serpentine and Amphibole. The division between the two types of asbestos is based upon the crystalline structure.

Serpentines have a sheet or layered structure where amphiboles have a chain-like structure. As the only member of the serpentine group, Chrysotile (A, B) is the most common type of asbestos found in buildings. Chrysotile makes up approximately 90%-95% of all asbestos contained in buildings in the United States.

Unlike most minerals, which turn into dust particles when crushed, asbestos breaks up into fine fibers that are too small to be seen by the human eye. Often, individual fibers are mixed with a material that binds them together, producing asbestos-containing material (**ACM**).

Health Effects of Asbestos Exposure

Asbestos is the largest single cause of fatal disease and ill-health caused by work in Great Britain. Although almost all the deaths and ill health related to asbestos today are due to exposures that happened several decades ago, if you work with asbestos, or come into contact with it as a result of repair and maintenance work, you need to be particularly careful. Asbestos can be found in most buildings built between 1950 and 1980, as insulation and lagging. It is still used in some brake pads and clutch linings and can be met in vehicle servicing and repair.

Asbestos-Related Health Problems

Some people exposed to asbestos develop asbestos-related health problems; some do not. Once inhaled, asbestos fibers can easily penetrate body tissues. They may be deposited and retained in the airways and lung tissue. Because asbestos fibers remain in the body, each exposure increases the likelihood of developing an asbestos-related disease. Asbestos-related diseases may not appear until years after exposure. A medical examination that includes a medical history, breathing capacity test, and chest X ray may detect problems early.

Many substances have a "**safe dose**" or an exposure that is unlikely to cause any harm. Above the safe dose, a health effect is expected. This concept is known as a dose response. As the dose increases, so does the expected severity of the health effect. However, in the case of asbestos, scientists have not determined a "**safe dose**" or threshold level for exposure to airborne asbestos. Still, the less exposure a person receives over a lifetime, the less likely it is that that person will develop an asbestos-related health problem.

In addition to breathing it, ingesting asbestos may also be harmful to you, but the consequences of this type of exposure have not been clearly documented. People who touch asbestos may get a rash similar to the rash caused by fiberglass. While the effects of skin exposure to asbestos have not been scientifically documented, it is best to minimize all contact with asbestos.

Asbestos was used in approximately 3,000 products. Two-thirds of this total (2,000) was used in construction products. Appendix A includes a short list of products where asbestos may be found.

Barium - Inorganic Contaminant 2 mg/L Water MCL

In 1974, Congress passed the Safe Drinking Water Act. This law requires EPA to determine the level of contaminants in drinking water at which no adverse health effects are likely to occur. These non-enforceable health goals, based solely on possible health risks and exposure over a lifetime with an adequate margin of safety, are called maximum contaminant level goals (MCLG). Contaminants are any physical, chemical, biological or radiological substances or matter in water.

The MCLG for barium is 2 mg/L or 2 ppm. EPA has set this level of protection based on the best available science to prevent potential health problems. EPA has set an enforceable regulation for barium, called a maximum contaminant level (MCL), at 2 mg/L or 2 ppm. MCLs are set as close to the health goals as possible, considering cost, benefits and the ability of public water systems to detect and remove contaminants using suitable treatment technologies. In this case, the MCL equals the MCLG, because analytical methods or treatment technology do not pose any limitation.



The Phase IIB Rule, the regulation for barium, became effective in 1993. The Safe Drinking Water Act requires EPA to periodically review the national primary drinking water regulation for each contaminant and revise the regulation, if appropriate. EPA reviewed barium as part of the Six Year Review and determined that the 2 mg/L or 2 ppm MCLG and 2 mg/L or 2 ppm MCL for barium are still protective of human health.

The major sources of barium in drinking water are discharge of drilling wastes; discharge from metal refineries; and erosion of natural deposits.

A federal law called the Emergency Planning and Community Right to Know Act (EPCRA) requires facilities in certain industries, which manufacture, process, or use significant amounts of toxic chemicals, to report annually on their releases of these chemicals. For more information on the uses and releases of chemicals in your state, contact the Community Right-to-Know Hotline: (800) 424-9346.

When routine monitoring indicates that barium levels are above the MCL, your water supplier must take steps to reduce the amount of barium so that it is below that level. Water suppliers must notify their customers as soon as practical, but no later than 30 days after the system learns of the violation. Additional actions, such as providing alternative drinking water supplies, may be required to prevent serious risks to public health.

How will barium be removed from my Drinking Water?

The following treatment method(s) have proven to be effective for removing barium to below 2 mg/L or 2 ppm: ion exchange, reverse osmosis, lime softening, and electrodialysis.

How do I learn more about my Drinking Water?

EPA strongly encourages people to learn more about their drinking water, and to support local efforts to protect the supply of safe drinking water and upgrade the community water system. Your water bill or telephone book's government listings are a good starting point for local information.

Barium Explained

Barium is a chemical element with symbol **Ba** and atomic number 56. It is the fifth element in Group 2, a soft silvery metallic alkaline earth metal. Because of its high chemical reactivity barium is never found in nature as a free element. Its hydroxide was known in pre-modern history as baryta; this substance does not occur as a mineral, but can be prepared by heating barium carbonate.

The most common naturally occurring minerals of barium are barite (barium sulfate, BaSO₄) and witherite (barium carbonate, BaCO₃), both being insoluble in water. Barium's name originates from the alchemical derivative "baryta", which itself comes from Greek βαρύς (*barys*), meaning "heavy." Barium was identified as a new element in 1774, but not reduced to a metal until 1808, shortly after electrolytic isolation techniques became available.

Barium has only a few industrial applications. The metal has been historically used to scavenge air in vacuum tubes. It is a component of YBCO (high-temperature superconductors) and electroceramics, and is added to steel and cast iron to reduce the size of carbon grains within the microstructure of the metal. Barium compounds are added to fireworks to impart a green color. For instance, barium sulfate is used as an insoluble heavy additive to oil well drilling fluid, and in purer form, as X-ray radiocontrast agents for imaging the human gastrointestinal tract. Soluble barium compounds are poisonous due to release of the soluble barium ion, and therefore have been used as rodenticides.

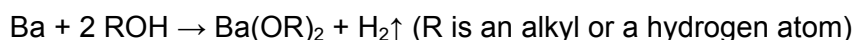
Physical Properties

Barium is a soft, silvery-white metal, with a slight golden shade when ultrapure. The silvery-white color of barium metal rapidly vanishes upon oxidation in air yielding a dark gray oxide layer. Barium has a medium specific weight and good electrical conductivity. Ultrapure barium is very hard to prepare, and therefore many properties of barium have not been accurately measured yet.

At room temperature and pressure, barium has a body-centered cubic structure, with a barium–barium distance of 503 picometers, expanding with heating at a rate of approximately $1.8 \times 10^{-5} / ^\circ\text{C}$. It is a very soft metal with a Mohs hardness of 1.25. Its melting temperature of 1000 K (727 °C, 1341 °F) is intermediate between those of the lighter strontium (1050 K) and heavier radium (973 K); however, its boiling point of 2170 K (1897 °C, 3447 °F) exceeds that of strontium (1655 K). The density ($3.62 \text{ g}\cdot\text{cm}^{-3}$) is again intermediate between those of strontium ($2.36 \text{ g}\cdot\text{cm}^{-3}$) and radium ($\sim 5 \text{ g}\cdot\text{cm}^{-3}$).

Chemical Reactivity

Barium is chemically similar to magnesium, calcium, and strontium, being even more reactive. It always exhibits the oxidation state of +2. Reactions with chalcogens are highly exothermic (release energy); the reaction with oxygen or air occurs at room temperature, and therefore barium is stored under oil or inert gas atmosphere. Reactions with other nonmetals, such as carbon, nitrogen, phosphorus, silicon, and hydrogen, are generally exothermic and proceed upon heating. Reactions with water and alcohols are also very exothermic and release hydrogen gas:



Additionally, barium reacts with ammonia to form complexes such as Ba(NH₃)₆.

The metal is readily attacked by most acids. Sulfuric acid is a notable exception, as passivation stops the reaction by forming the insoluble barium sulfate. Barium combines with several metals, including aluminum, zinc, lead, and tin, forming intermetallic phases and alloys.

Compounds

Selected alkaline earth and zinc salts densities,
g·cm⁻³

	O ²⁻	S ²⁻	F ⁻	Cl ⁻	SO ₄ ²⁻	CO ₃ ²⁻	O ₂ ²⁻	H ⁻
Ca ²⁺ [9]	3.34	2.59	3.18	2.15	2.96	2.83	2.9	1.7
Sr ²⁺ [10]	5.1	3.7	4.24	3.05	3.96	3.5	4.78	3.26
Ba ²⁺ [11]	5.72	4.3	2.1	1.9	4.49	4.29	4.96	4.16
Zn ²⁺ [12]	5.6	4.09	4.9	2.09	3.8	4.4	1.57	—

Barium salts are typically white when solid and colorless when dissolved, as barium ions provide no specific coloring. They are also denser than their strontium or calcium analogs, except for the halides.

Barium hydroxide ("baryta") was known to alchemists who produced it by heating barium carbonate. Unlike calcium hydroxide, it absorbs very little CO₂ in aqueous solutions and is therefore insensitive to atmospheric fluctuations. This property is used in calibrating pH equipment.

Volatile barium compounds burn with a green to pale green flame, which is an efficient test to detect a barium compound. The color results from spectral lines at 455.4, 493.4, 553.6, and 611.1 nm.

Organobarium compounds are a growing class of compounds: for example, dialkylbariums are known, as are alkylhalobariums.

Isotopes of Barium

Barium occurs naturally on Earth as a mixture of seven primordial nuclides, barium-130, 132, and 134 through 138. The first two are thought to be radioactive: barium-130 should decay to xenon-130 via double beta plus decay, and barium-132 should similarly decay to xenon-132. The corresponding half-lives should exceed the age of the Universe by at least thousand times. Their abundances are ~0.1% relative to that of natural barium. Their radioactivity is so weak that they pose no danger to life. Out of the stable isotopes, barium-138 makes up 71.7% of all barium, and the lighter the isotope, the less it is abundant. In total, barium has about 50 known isotopes, ranging in mass between 114 and 153. The most stable metastable isotope is barium-133, which has a half-life of approximately 10.51 years, and five more isotopes have their half-lives longer than a day. Barium also has 10 meta states, out of which barium-133m1 is the most stable, having a half-life of about 39 hours.

Biological Dangers and Precautions

Because of the high reactivity of the metal toxicological data are available only for compounds. Water-soluble barium compounds are poisonous. At low doses, barium ions act as a muscle stimulant, whereas higher doses affect the nervous system, causing cardiac irregularities, tremors, weakness, anxiety, dyspnea and paralysis. This may be due to the ability of Ba^{2+} to block potassium ion channels, which are critical to the proper function of the nervous system. Other target organs for water-soluble barium compounds (i.e., barium ions) are eyes, immune system, heart, respiratory system, and skin. They affect the body strongly, causing, for example, blindness and sensitization.

Barium is not carcinogenic, and it does not bioaccumulate. However, inhaled dust containing insoluble barium compounds can accumulate in the lungs, causing a benign condition called baritosis. For comparison to the soluble poisons, the insoluble sulfate is nontoxic and is thus not classified as a dangerous good.

To avoid a potentially vigorous chemical reaction, barium metal is kept under argon or mineral oils. Contact with air is dangerous, as it may cause ignition. Moisture, friction, heat, sparks, flames, shocks, static electricity, reactions with oxidizers and acids should be avoided. Everything that may make contact with barium should be grounded. Those who work with the metal should wear pre-cleaned non-sparking shoes, flame-resistant rubber clothes, rubber gloves, apron, goggles, and a gas mask; they are not allowed to smoke in the working area and must wash themselves after handling barium.

Beryllium - Inorganic Contaminant 0.004 mg/L MCL

In 1974, Congress passed the Safe Drinking Water Act. This law requires EPA to determine the level of contaminants in drinking water at which no adverse health effects are likely to occur. These non-enforceable health goals, based solely on possible health risks and exposure over a lifetime with an adequate margin of safety, are called maximum contaminant level goals (MCLG). Contaminants are any physical, chemical, biological or radiological substances or matter in water.

The MCLG for beryllium is 0.004 mg/L or 4 ppb. EPA has set this level of protection based on the best available science to prevent potential health problems. EPA has set an enforceable regulation for beryllium, called a maximum contaminant level (MCL), at 0.004 mg/L or 4 ppb. MCLs are set as close to the health goals as possible, considering cost, benefits and the ability of public water systems to detect and remove contaminants using suitable treatment technologies. In this case, the MCL equals the MCLG, because analytical methods or treatment technology do not pose any limitation.



The Phase V Rule, the regulation for beryllium, became effective in 1994. The Safe Drinking Water Act requires EPA to periodically review the national primary drinking water regulation for each contaminant and revise the regulation, if appropriate. EPA reviewed beryllium as part of the Six Year Review and determined that the 0.004 mg/L or 4 ppb MCLG and 0.004 mg/L or 4 ppb MCL for beryllium are still protective of human health.

How does Beryllium get into my Drinking Water?

Beryllium naturally enters surface water and ground water through the weathering of rocks and soils or from industrial wastewater discharges. The major source of environmental releases from human activities are coal and fuel oil combustion.

A federal law called the Emergency Planning and Community Right to Know Act (EPCRA) requires facilities in certain industries, which manufacture, process, or use significant amounts of toxic chemicals, to report annually on their releases of these chemicals. For more information on the uses and releases of chemicals in your state, contact the Community Right-to-Know Hotline: (800) 424-9346.

How will I know if Beryllium is in my Drinking Water?

When routine monitoring indicates that beryllium levels are above the MCL, your water supplier must take steps to reduce the amount of beryllium so that it is below that level. Water suppliers must notify their customers as soon as practical, but no later than 30 days after the system learns of the violation. Additional actions, such as providing alternative drinking water supplies, may be required to prevent serious risks to public health.

Beryllium Explained

Beryllium is the chemical element with the symbol **Be** and atomic number 4. Because any beryllium synthesized in stars is short-lived, it is a relatively rare element in both the universe and in the crust of the Earth. It is a divalent element which occurs naturally only in combination with other elements in minerals. Notable gemstones which contain beryllium include beryl (aquamarine, emerald) and chrysoberyl. As a free element it is a steel-gray, strong, lightweight and brittle alkaline earth metal.

Beryllium increases hardness and resistance to corrosion when alloyed to aluminum, cobalt, copper (notably beryllium copper), iron and nickel. In structural applications, high flexural rigidity, thermal stability, thermal conductivity and low density (1.85 times that of water) make beryllium a quality aerospace material for high-speed aircraft, missiles, space vehicles and communication satellites. Because of its low density and atomic mass, beryllium is relatively transparent to X-rays and other forms of ionizing radiation; therefore, it is the most common window material for X-ray equipment and in particle physics experiments. The high thermal conductivities of beryllium and beryllium oxide have led to their use in heat transport and heat sinking applications.

The commercial use of beryllium metal presents technical challenges due to the toxicity (especially by inhalation) of beryllium-containing dusts. Beryllium is corrosive to tissue, and can cause a chronic life-threatening allergic disease called berylliosis in some people. The element is not known to be necessary or useful for either plant or animal life

Characteristics

Physical Properties

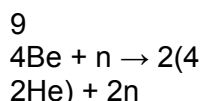
Beryllium is a steel gray and hard metal that is brittle at room temperature and has a close-packed hexagonal crystal structure. It has exceptional flexural rigidity (Young's modulus 287 GPa) and a reasonably high melting point. The modulus of elasticity of beryllium is approximately 50% greater than that of steel. The combination of this modulus and a relatively low density results in an unusually fast sound conduction speed in beryllium – about 12.9 km/s at ambient conditions. Other significant properties are high specific heat ($1925 \text{ J}\cdot\text{kg}^{-1}\cdot\text{K}^{-1}$) and thermal conductivity ($216 \text{ W}\cdot\text{m}^{-1}\cdot\text{K}^{-1}$), which make beryllium the metal with the best heat dissipation characteristics per unit weight. In combination with the relatively low coefficient of linear thermal expansion ($11.4\times 10^{-6} \text{ K}^{-1}$), these characteristics result in a unique stability under conditions of thermal loading.

Nuclear Properties

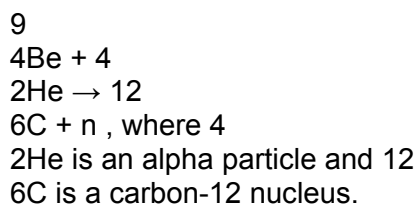
Natural beryllium, save for slight contamination by cosmogenic radioisotopes, is essentially beryllium-9, which has a nuclear spin of $3/2^-$. Beryllium has a large scattering cross section for high-energy neutrons, about 6 barns for energies above $\sim 0.01 \text{ MeV}$. Therefore, it works as a neutron reflector and neutron moderator, effectively slowing the neutrons to the thermal energy range of below 0.03 eV , where the total cross section is at least an order of magnitude lower – exact value strongly depends on the purity and size of the crystallites in the material.

The single primordial beryllium isotope ^9Be also undergoes a $(n,2n)$ neutron reaction with neutron energies over about 1.9 MeV , to produce ^8Be , which almost immediately breaks into two alpha particles. Thus, for high-energy neutrons beryllium is a neutron multiplier, releasing more neutrons than it absorbs.

This nuclear reaction is:



Neutrons are liberated when beryllium nuclei are struck by energetic alpha particles producing the nuclear reaction



Beryllium also releases neutrons under bombardment by gamma rays. Thus, natural beryllium bombarded either by alphas or gammas from a suitable radioisotope is a key component of most radioisotope-powered nuclear reaction neutron sources for the laboratory production of free neutrons.

As a metal, beryllium is transparent to most wavelengths of X-rays and gamma rays, making it useful for the output windows of X-ray tubes and other such apparatus.

Isotopes and Nucleosynthesis

Both stable and unstable isotopes of beryllium are created in stars, but these do not last long. It is believed that most of the stable beryllium in the universe was originally created in the interstellar medium when cosmic rays induced fission in heavier elements found in interstellar gas and dust. Primordial beryllium contains only one stable isotope, ${}^9\text{Be}$, and therefore beryllium is a monoisotopic element.

Plot showing variations in solar activity, including variation in ${}^{10}\text{Be}$ concentration. Note that the beryllium scale is inverted, so increases on this scale indicate lower ${}^{10}\text{Be}$ levels

Radioactive cosmogenic ${}^{10}\text{Be}$ is produced in the atmosphere of the Earth by the cosmic ray spallation of oxygen. ${}^{10}\text{Be}$ accumulates at the soil surface, where its relatively long half-life (1.36 million years) permits a long residence time before decaying to boron-10. Thus, ${}^{10}\text{Be}$ and its daughter products are used to examine natural soil erosion, soil formation and the development of lateritic soils, and as a proxy for measurement of the variations in solar activity and the age of ice cores. The production of ${}^{10}\text{Be}$ is inversely proportional to solar activity, because increased solar wind during periods of high solar activity decreases the flux of galactic cosmic rays that reach the Earth. Nuclear explosions also form ${}^{10}\text{Be}$ by the reaction of fast neutrons with ${}^{13}\text{C}$ in the carbon dioxide in air. This is one of the indicators of past activity at nuclear weapon test sites. The isotope ${}^7\text{Be}$ (half-life 53 days) is also cosmogenic, and shows an atmospheric abundance linked to sunspots, much like ${}^{10}\text{Be}$.

${}^8\text{Be}$ has a very short half-life of about 7×10^{-17} s that contributes to its significant cosmological role, as elements heavier than beryllium could not have been produced by nuclear fusion in the Big Bang. This is due to the lack of sufficient time during the Big Bang's nucleosynthesis phase to produce carbon by the fusion of ${}^4\text{He}$ nuclei and the very low concentrations of available beryllium-8.

The British astronomer Sir Fred Hoyle first showed that the energy levels of ^8Be and ^{12}C allow carbon production by the so-called triple-alpha process in helium-fueled stars where more nucleosynthesis time is available. This process allows carbon to be produced in stars, but not in the Big Bang. Star-created carbon (the basis of carbon-based life) is thus a component in the elements in the gas and dust ejected by AGB stars and supernovae (see also Big Bang nucleosynthesis), as well as the creation of all other elements with atomic numbers larger than that of carbon.

The innermost electrons of beryllium may contribute to chemical bonding. Therefore, when ^7Be decays by electron capture, it does so by taking electrons from atomic orbitals that may participate in bonding. This makes its decay rate dependent to a measurable degree upon its electron configuration – a rare occurrence in nuclear decay.

The shortest-lived known isotope of beryllium is ^{13}Be which decays through neutron emission. It has a half-life of 2.7×10^{-21} s. ^6Be is also very short-lived with a half-life of 5.0×10^{-21} s. The exotic isotopes ^{11}Be and ^{14}Be are known to exhibit a nuclear halo. This phenomenon can be understood as the nuclei of ^{11}Be and ^{14}Be have, respectively, 1 and 4 neutrons orbiting substantially outside the classical Fermi 'water drop' model of the nucleus.

Occurrence

Beryllium has a concentration of 2 to 6 parts per million (ppm) in the Earth's crust. The Sun has a concentration of 0.1 parts per billion (ppb) of beryllium, similar to that of rhenium. It is most concentrated in the soils, 6 ppm, and is found in 0.2 parts per trillion (ppt) of sea water. Trace amounts of ^9Be are found in the Earth's atmosphere. In sea water, beryllium is exceedingly rare, more so than even scandium, comprising only 0.0006 ppb by weight. In stream water, however, beryllium is more abundant with 0.1 ppb by weight.

Beryllium is found in over 100 minerals, but most are uncommon to rare. The more common beryllium containing minerals include: bertrandite ($\text{Be}_4\text{Si}_2\text{O}_7(\text{OH})_2$), beryl ($\text{Al}_2\text{Be}_3\text{Si}_6\text{O}_{18}$), chrysoberyl (Al_2BeO_4) and phenakite (Be_2SiO_4). Precious forms of beryl are aquamarine, bixbite and emerald. The green color in gem-quality forms of beryl comes from varying amounts of chromium (about 2% for emerald).

The two main ores of beryllium, beryl and bertrandite, are found in Argentina, Brazil, India, Madagascar, Russia and the United States. Total world reserves of beryllium ore are greater than 400,000 tons.

Production

The extraction of beryllium from its compounds is a difficult process due to its high affinity for oxygen at elevated temperatures, and its ability to reduce water when its oxide film is removed. The United States, China and Kazakhstan are the only three countries involved in the industrial scale extraction of beryllium.

Beryllium is most-commonly extracted from beryl, which is either sintered using an extraction agent or melted into a soluble mixture. The sintering process involves mixing beryl with sodium fluorosilicate and soda at 770°C to form sodium fluoroberyllate, aluminum oxide and silicon dioxide. Beryllium hydroxide is precipitated from a solution of sodium fluoroberyllate and sodium hydroxide in water. Extraction of beryllium using the melt method involves grinding beryl into a powder and heating it to 1650°C . The melt is quickly cooled with water and then reheated 250 to 300°C in concentrated sulfuric acid, mostly yielding beryllium sulfate and aluminum sulfate.

Aqueous ammonia is then used to remove the aluminum and sulfur, leaving beryllium hydroxide.

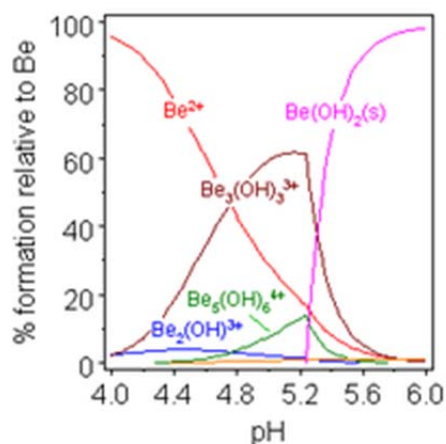
Beryllium hydroxide created using either the sinter or melt method is then converted into beryllium fluoride or beryllium chloride. To form the fluoride, aqueous ammonium hydrogen fluoride is added to beryllium hydroxide to yield a precipitate of ammonium tetrafluoroberyllate, which is heated to 1000°C to form beryllium fluoride.

Heating the fluoride to 900°C with magnesium forms finely divided beryllium and additional heating to 1300°C creates the compact metal. Heating beryllium hydroxide forms the oxide which becomes beryllium chloride when mixed with carbon and chloride. Electrolysis of molten beryllium chloride is then used to obtain the metal.

Chemical Properties

Beryllium's chemical behavior is largely a result of its small atomic and ionic radii. It thus has very high ionization potentials and strong polarization while bonded to other atoms, which is why all of its compounds are covalent. It is more chemically similar to aluminum than its close neighbors in the periodic table due to having a similar charge-to-radius ratio. An oxide layer forms around beryllium that prevents further reactions with air unless heated above 1000°C.

Once ignited, beryllium burns brilliantly forming a mixture of beryllium oxide and beryllium nitride. Beryllium dissolves readily in non-oxidizing acids, such as HCl and diluted H₂SO₄, but not in nitric acid or water as this forms the oxide. This behavior is similar to that of aluminum metal. Beryllium also dissolves in alkali solutions.

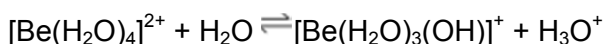


Beryllium hydrolysis as a function of pH
Water molecules attached to Be are omitted

The beryllium atom has the electronic configuration [He] 2s². The two valence electrons give beryllium a +2 oxidation state and thus the ability to form two covalent bonds; the only evidence of lower valence of beryllium is in the solubility of the metal in BeCl₂. Due to the octet rule, atoms tend to seek a valence of 8 in order to resemble a noble gas. Beryllium tries to achieve a coordination number of 4 because its two covalent bonds fill half of this octet. A coordination of 4 allows beryllium compounds, such as the fluoride or chloride, to form polymers.

This characteristic is employed in analytical techniques using EDTA as a ligand. EDTA preferentially forms octahedral complexes – thus absorbing other cations such as Al^{3+} which might interfere – for example, in the solvent extraction of a complex formed between Be^{2+} and acetylacetone. Beryllium(II) readily forms complexes with strong donating ligands such as phosphine oxides and arsine oxides. There have been extensive studies of these complexes which show the stability of the O-Be bond.

Solutions of beryllium salts, e.g. beryllium sulfate and beryllium nitrate, are acidic because of hydrolysis of the $[\text{Be}(\text{H}_2\text{O})_4]^{2+}$ ion.



Other products of hydrolysis include the trimeric ion $[\text{Be}_3(\text{OH})_3(\text{H}_2\text{O})_6]^{3+}$. Beryllium hydroxide, $\text{Be}(\text{OH})_2$, is insoluble even in acidic solutions with pH less than 6, that is at biological pH. It is amphoteric and dissolves in strongly alkaline solutions.

Beryllium forms binary compounds with many non-metals. Anhydrous halides are known for F, Cl, Br and I. BeF_2 has a silica-like structure with corner-shared BeF_4 tetrahedra. BeCl_2 and BeBr_2 have chain structures with edge-shared tetrahedra. All beryllium halides have a linear monomeric molecular structure in the gas phase.

Beryllium difluoride, BeF_2 , is different than the other difluorides. In general, beryllium has a tendency to bond covalently, much more so than the other alkaline earths and its fluoride is partially covalent (although still more ionic than its other halides). BeF_2 has many similarities to SiO_2 (quartz) a mostly covalently bonded network solid. BeF_2 has tetrahedrally coordinated metal and forms glasses (is difficult to crystallize). When crystalline, beryllium fluoride has the same room temperature crystal structure as quartz and shares many higher temperatures structures also. Beryllium difluoride is very soluble in water, unlike the other alkaline earths. (Although they are strongly ionic, they do not dissolve because of the especially strong lattice energy of the fluorite structure.) However, BeF_2 has much lower electrical conductivity when in solution or when molten than would be expected if it were fully ionic.

Beryllium Oxide

Beryllium oxide, BeO , is a white refractory solid, which has the wurtzite crystal structure and a thermal conductivity as high as in some metals. BeO is amphoteric. Salts of beryllium can be produced by treating $\text{Be}(\text{OH})_2$ with acid. Beryllium sulfide, selenide and telluride are known, all having the zincblende structure.

Beryllium Nitride

Beryllium nitride, Be_3N_2 is a high-melting-point compound which is readily hydrolyzed. Beryllium azide, BeN_6 is known and beryllium phosphide, Be_3P_2 has a similar structure to Be_3N_2 . Basic beryllium nitrate and basic beryllium acetate have similar tetrahedral structures with four beryllium atoms coordinated to a central oxide ion. A number of beryllium borides are known, such as Be_5B , Be_4B , Be_2B , BeB_2 , BeB_6 and BeB_{12} . Beryllium carbide, Be_2C , is a refractory brick-red compound that reacts with water to give methane. No beryllium silicide has been identified.

Approximately 35 micrograms of beryllium is found in the human body, but this amount is not considered harmful. Beryllium is chemically similar to magnesium and therefore can displace it from enzymes, which causes them to malfunction.

Chronic berylliosis is a pulmonary and systemic granulomatous disease caused by inhalation of dust or fumes contaminated with beryllium; either large amounts over a short time or small

amounts over a long time can lead to this ailment. Symptoms of the disease can take up to 5 years to develop; about a third of patients with it die and the survivors are left disabled. The International Agency for Research on Cancer (IARC) lists beryllium and beryllium compounds as Category 1 carcinogens.

Acute beryllium disease in the form of chemical pneumonitis was first reported in Europe in 1933 and in the United States in 1943. A survey found that about 5% of workers in plants manufacturing fluorescent lamps in 1949 in the United States had beryllium-related lung diseases. Chronic berylliosis resembles sarcoidosis in many respects, and the differential diagnosis is often difficult. It killed some early workers in nuclear weapons design, such as Herbert L. Anderson.

Early researchers tasted beryllium and its various compounds for sweetness in order to verify its presence. Modern diagnostic equipment no longer necessitates this highly risky procedure and no attempt should be made to ingest this highly toxic substance. Beryllium and its compounds should be handled with great care and special precautions must be taken when carrying out any activity which could result in the release of beryllium dust (lung cancer is a possible result of prolonged exposure to beryllium laden dust). Although the use of beryllium compounds in fluorescent lighting tubes was discontinued in 1949, potential for exposure to beryllium exists in the nuclear and aerospace industries and in the refining of beryllium metal and melting of beryllium-containing alloys, the manufacturing of electronic devices, and the handling of other beryllium-containing material.

A successful test for beryllium in air and on surfaces has been recently developed and published as an international voluntary consensus standard ASTM D7202. The procedure uses dilute ammonium bifluoride for dissolution and fluorescence detection with beryllium bound to sulfonated hydroxybenzoquinoline, allowing up to 100 times more sensitive detection than the recommended limit for beryllium concentration in the workplace. Fluorescence increases with increasing beryllium concentration. The new procedure has been successfully tested on a variety of surfaces and is effective for the dissolution and ultratrace detection of refractory beryllium oxide and siliceous beryllium (ASTM D7458).

Cadmium - Inorganic Contaminant 0.005 mg/L Water MCL

In 1974, Congress passed the Safe Drinking Water Act. This law requires EPA to determine the level of contaminants in drinking water at which no adverse health effects are likely to occur. These non-enforceable health goals, based solely on possible health risks and exposure over a lifetime with an adequate margin of safety, are called maximum contaminant level goals (MCLG). Contaminants are any physical, chemical, biological or radiological substances or matter in water.

The MCLG for cadmium is 0.005 mg/L or 5 ppb. EPA has set this level of protection based on the best available science to prevent potential health problems. EPA has set an enforceable regulation for cadmium, called a maximum contaminant level (MCL), at 0.005 mg/L or 5 ppb. MCLs are set as close to the health goals as possible, considering cost, benefits and the ability of public water systems to detect and remove contaminants using suitable treatment technologies. In this case, the MCL equals the MCLG, because analytical methods or treatment technology do not pose any limitation.



The Phase II Rule, the regulation for cadmium, became effective in 1992. The Safe Drinking Water Act requires EPA to periodically review the national primary drinking water regulation for each contaminant and revise the regulation, if appropriate. EPA reviewed cadmium as part of the Six Year Review and determined that the 0.005 mg/L or 5 ppb MCLG and 0.005 mg/L or 5 ppb MCL for cadmium are still protective of human health.

How does cadmium get into my drinking water?

The major sources of cadmium in drinking water are corrosion of galvanized pipes; erosion of natural deposits; discharge from metal refineries; runoff from waste batteries and paints. A federal law called the Emergency Planning and Community Right to Know Act (EPCRA) requires facilities in certain industries, which manufacture, process, or use significant amounts of toxic chemicals, to report annually on their releases of these chemicals. For more information on the uses and releases of chemicals in your state, contact the Community Right-to-Know Hotline: (800) 424-9346.

How will I know if cadmium is in my drinking water?

When routine monitoring indicates that cadmium levels are above the MCL, your water supplier must take steps to reduce the amount of cadmium so that it is below that level. Water suppliers must notify their customers as soon as practical, but no later than 30 days after the system learns of the violation. Additional actions, such as providing alternative drinking water supplies, may be required to prevent serious risks to public health.

If your water comes from a household well, check with your health department or local water systems that use ground water for information on contaminants of concern in your area.

How will cadmium be removed from my drinking water?

The following treatment method(s) have proven to be effective for removing cadmium to below 0.005 mg/L or 5 ppb: coagulation/filtration, ion exchange, lime softening, and reverse osmosis.

Cadmium Explained

Cadmium is a chemical element with the symbol **Cd** and atomic number 48. This soft, bluish-white metal is chemically similar to the two other stable metals in group 12, zinc and mercury. Like zinc, it prefers oxidation state +2 in most of its compounds and like mercury it shows a low melting point compared to transition metals. Cadmium and its congeners are not always considered transition metals, in that they do not have partly filled d or f electron shells in the elemental or common oxidation states. The average concentration of cadmium in the Earth's crust is between 0.1 and 0.5 parts per million (ppm). It was discovered in 1817 simultaneously by Stromeyer and Hermann, both in Germany, as an impurity in zinc carbonate.

Cadmium occurs as a minor component in most zinc ores and therefore is a byproduct of zinc production. It was used for a long time as a pigment and for corrosion resistant plating on steel while cadmium compounds were used to stabilize plastic. With the exception of its use in nickel–cadmium batteries and cadmium telluride solar panels, the use of cadmium is generally decreasing. These declines have been due to competing technologies, cadmium's toxicity in certain forms and concentration and resulting regulations. Although cadmium has no known biological function in higher organisms, a cadmium-dependent carbonic anhydrase has been found in marine diatoms.

Characteristics

Physical Properties

Cadmium is a soft, malleable, ductile, bluish-white divalent metal. It is similar in many respects to zinc but forms complex compounds. Unlike other metals, cadmium is resistant to corrosion and as a result it is used as a protective layer when deposited on other metals. As a bulk metal, cadmium is insoluble in water and is not flammable; however, in its powdered form it may burn and release toxic fumes.

Chemical Properties

Although cadmium usually has an oxidation state of +2, it also exists in the +1 state. Cadmium and its congeners are not always considered transition metals, in that they do not have partly filled d or f electron shells in the elemental or common oxidation states. Cadmium burns in air to form brown amorphous cadmium oxide (CdO); the crystalline form of this compound is a dark red which changes color when heated, similar to zinc oxide. Hydrochloric acid, sulfuric acid and nitric acid dissolve cadmium by forming cadmium chloride (CdCl₂), cadmium sulfate (CdSO₄), or cadmium nitrate (Cd(NO₃)₂). The oxidation state +1 can be reached by dissolving cadmium in a mixture of cadmium chloride and aluminum chloride, forming the Cd₂²⁺ cation, which is similar to the Hg₂²⁺ cation in mercury(I) chloride.



Isotopes

Naturally occurring cadmium is composed of 8 isotopes. Two of them are naturally radioactive, and three are expected to decay but have not been experimentally confirmed to do so. The two natural radioactive isotopes are ¹¹³Cd (beta decay, half-life is 7.7 × 10¹⁵ years) and ¹¹⁶Cd (two-neutrino double beta decay, half-life is 2.9 × 10¹⁹ years).

The other three are ^{106}Cd , ^{108}Cd (both double electron capture), and ^{114}Cd (double beta decay); only lower limits on their half-life times have been set. At least three isotopes – ^{110}Cd , ^{111}Cd , and ^{112}Cd – are stable.

Among the isotopes that do not occur naturally, the most long-lived are ^{109}Cd with a half-life of 462.6 days, and ^{115}Cd with a half-life of 53.46 hours. All of the remaining radioactive isotopes have half-lives that are less than 2.5 hours, and the majority of these have half-lives that are less than 5 minutes. Cadmium has 8 known meta states, with the most stable being $^{113\text{m}}\text{Cd}$ ($t_{1/2} = 14.1$ years), $^{115\text{m}}\text{Cd}$ ($t_{1/2} = 44.6$ days), and $^{117\text{m}}\text{Cd}$ ($t_{1/2} = 3.36$ hours).

The known isotopes of cadmium range in atomic mass from 94.950 u (^{95}Cd) to 131.946 u (^{132}Cd). For isotopes lighter than 112 u, the primary decay mode is electron capture and the dominant decay product is element 47 (silver). Heavier isotopes decay mostly through beta emission producing element 49 (indium).

One isotope of cadmium, ^{113}Cd , absorbs neutrons with very high probability if they have an energy below the *cadmium cut-off* and transmits them otherwise. The cadmium cut-off is about 0.5 eV. Neutrons with energy below the cut-off are deemed slow neutrons, distinguishing them from intermediate and fast neutrons.

Cadmium is created via the long s-process in low-medium mass stars with masses of 0.6 to 10 solar masses, which lasts thousands of years. It requires a silver atom to capture a neutron and then undergo beta decay.

Cadmium makes up about 0.1 ppm of the Earth's crust. Compared with the more abundant 65 ppm zinc, cadmium is rare. No significant deposits of cadmium-containing ores are known. Greenockite (CdS), the only cadmium mineral of importance, is nearly always associated with sphalerite (ZnS). This association is caused by the geochemical similarity between zinc and cadmium which makes geological separation unlikely. As a consequence, cadmium is produced mainly as a byproduct from mining, smelting, and refining sulfidic ores of zinc, and, to a lesser degree, lead and copper.

Small amounts of cadmium, about 10% of consumption, are produced from secondary sources, mainly from dust generated by recycling iron and steel scrap. Production in the United States began in 1907, but it was not until after World War I that cadmium came into wide use. One place where metallic cadmium can be found is the Vilyuy River basin in Siberia.

Rocks mined to produce phosphate fertilizers contain varying amounts of cadmium, leading to a cadmium concentration of up to 300 mg/kg in the produced phosphate fertilizers and thus in the high cadmium content in agricultural soils. Coal can contain significant amounts of cadmium, which ends up mostly in the flue dust.

Chromium- Inorganic Contaminant 0.1 mg/L Water MCL

The Safe Drinking Water Act requires EPA to determine the level of contaminants in drinking water at which no adverse health effects are likely to occur. These non-enforceable health goals, based on possible health risks from exposure over a lifetime, are called maximum contaminant level goals (MCLG).

EPA sets enforceable standards for drinking water contaminants based on the best available science to prevent potential health problems. In most cases, the enforceable standard is known as a maximum contaminant level (MCL), the maximum permissible level of a contaminant in water which is delivered to any user of a public water system. MCLs are set as close to the health goals as possible after considering costs, benefits and the ability of public water systems to detect and remove contaminants using suitable treatment technologies.

The national primary drinking water regulation that established the MCL for total chromium was promulgated in 1991. The Safe Drinking Water Act requires EPA to periodically review the national primary drinking water regulation for each contaminant and revise the regulation, if appropriate. EPA reviewed total chromium as part of the second six-year review that was announced in March 2010. The Agency noted in March 2010 that it had initiated a reassessment of the health risks associated with chromium exposure and that the Agency did not believe it was appropriate to revise the national primary drinking water regulation while that effort was in process. In 2008, EPA began a rigorous and comprehensive review of chromium-6 health effects based on new science. When this human health assessment is finalized EPA will carefully review the conclusions and consider all relevant information to determine if the current chromium standard should be revised

Ensuring safe drinking water for all Americans is a top priority for EPA. EPA has an enforceable drinking water standard of 0.1 milligrams per liter (mg/L) for total chromium, which includes chromium-6 and chromium-3. This standard was established in 1991 and was based on the best available science at the time which indicated that some people who use water containing chromium in excess of the drinking water standard over many years could experience allergic dermatitis (skin reactions).

EPA regularly re-evaluates drinking water standards and, based on new science on chromium-6, had begun a rigorous and comprehensive review of its health effects in 2008. In September 2010, EPA released a draft of that scientific assessment for public comment. When this human health assessment is finalized, EPA will carefully review the conclusions and consider all relevant information to determine if a new drinking water standard for chromium-6 or a revision to the current total chromium standard is warranted.

Chromium is an odorless and tasteless metallic element. Chromium is found naturally in rocks, plants, soil and volcanic dust, humans and animals. The most common forms of chromium that



occur in natural waters in the environment are trivalent chromium (chromium-3), and hexavalent chromium (chromium-6).

Chromium-3 is an essential human dietary element and occurs naturally in many vegetables, fruits, meats, grains and yeast. Chromium-6 occurs naturally in the environment from the erosion of natural chromium deposits but it can also be produced by industrial processes. There are demonstrated instances of chromium being released to the environment by leakage, poor storage, or inadequate industrial waste disposal practices.

What are some uses for Chromium?

Metallic chromium is used mainly for making steel and other alloys. Chromium compounds in either the chromium-3 or chromium-6 forms are used for chrome plating, dyes and pigments, leather and wood preservation.

What are Chromium's Health Effects?

Chromium-3 is a nutritionally essential element in humans and is often added to vitamins as a dietary supplement. Chromium-3 has relatively low toxicity and would be a concern in drinking water only at very high levels of contamination; Chromium-6 is more toxic and poses potential health risks. People who use water containing total chromium in excess of the maximum contaminant level (MCL) over many years could experience allergic dermatitis.

EPA proposed to classify chromium-6 as likely to be carcinogenic to humans when ingested. The Agency continues to work towards completing the human health assessment and making a final determination about the carcinogenicity of chromium-6. When the assessment is completed, EPA will determine whether the drinking water standard for total chromium needs to be revised.

What are EPA's drinking water regulations for Chromium?

The Safe Drinking Water Act requires EPA to determine the level of contaminants in drinking water at which no adverse health effects are likely to occur. These non-enforceable health goals, based on possible health risks from exposure over a lifetime are called maximum contaminant level goals (MCLG).

The MCLG for total chromium is 0.1 mg/L or 100 parts per billion (ppb). EPA has set this level of protection based on the best available science at the time the rule was promulgated. EPA has set an enforceable regulation for total chromium, called a maximum contaminant level (MCL), at 0.1 mg/L or 100 ppb. MCLs are set as close to the health goals as possible, considering cost, benefits and the ability of public water systems to detect and remove contaminants using suitable treatment technologies. In this case, the MCL equals the MCLG, because analytical methods or treatment technology do not pose any limitation.

States may set more stringent drinking water MCLGs and MCLs for total chromium than EPA.

Why are Chromium-6 and Chromium-3 covered in the same Standard?

Chromium-6 and chromium-3 are covered under the total chromium drinking water standard because these forms of chromium can convert back and forth in water and in the human body, depending on environmental conditions.

Measuring just one form may not capture all of the chromium that is present. In order to ensure that the greatest potential risk is addressed, EPA's regulation assumes that a measurement of total chromium is 100 percent chromium-6, the more toxic form.

How often does the EPA update the Total Chromium Drinking Water Standard?

The Safe Drinking Water Act requires EPA to periodically review the national primary drinking water regulation for each contaminant and revise the regulation, if appropriate. EPA reviewed total chromium as part of the second six-year review that was announced in March 2010. The Agency noted in March 2010 that it had initiated a reassessment of the health risks associated with chromium exposure and that the Agency did not believe it was appropriate to revise the national primary drinking water regulation while that effort was in process.

In 2008, EPA began a rigorous and comprehensive review of chromium-6 health effects based on new science. When this human health assessment is finalized EPA will carefully review the conclusions and consider all relevant information to determine if the current chromium standard should be revised.

Chromium Explained

Chromium Description

Chromium is a chemical element which has the symbol **Cr** and atomic number 24. It is the first element in Group 6. It is a steely-gray, lustrous, hard metal that takes a high polish and has a high melting point. It is also odorless, tasteless, and malleable. The name of the element is derived from the Greek word "chrōma" (χρῶμα), meaning color, because many of its compounds are intensely colored.

Chromium oxide was used by the Chinese in the Qin dynasty over 2,000 years ago to coat metal weapons found with the Terracotta Army. Chromium was discovered as an element after it came to the attention of the western world in the red crystalline mineral crocoite (lead(II) chromate), discovered in 1761 and initially used as a pigment. Louis Nicolas Vauquelin first isolated chromium metal from this mineral in 1797. Since Vauquelin's first production of metallic chromium, small amounts of native (free) chromium metal have been discovered in rare minerals, but these are not used commercially. Instead, nearly all chromium is commercially extracted from the single commercially viable ore chromite, which is iron chromium oxide (FeCr_2O_4). Chromite is also now the chief source of chromium for chromium pigments.

Chromium metal and ferrochromium alloy are commercially produced from chromite by silicothermic or aluminothermic reactions, or by roasting and leaching processes.

Chromium metal has proven of high value due to its high corrosion resistance and hardness. A major development was the discovery that steel could be made highly resistant to corrosion and discoloration by adding metallic chromium to form stainless steel. This application, along with chrome plating (electroplating with chromium) currently comprise 85% of the commercial use for the element, with applications for chromium compounds forming the remainder.

Trivalent chromium (Cr(III)) ion is possibly required in trace amounts for sugar and lipid metabolism, although the issue remains in debate. In larger amounts and in different forms, chromium can be toxic and carcinogenic. The most prominent example of toxic chromium is hexavalent chromium (Cr(VI)). Abandoned chromium production sites often require environmental cleanup.

Characteristics

Physical

Chromium is remarkable for its magnetic properties: it is the only elemental solid which shows antiferromagnetic ordering at room temperature (and below). Above 38 °C, it transforms into a paramagnetic state.

Passivation

Chromium metal left standing in air is passivated by oxygen, forming a thin protective oxide surface layer. This layer is a spinel structure only a few atoms thick. It is very dense, and prevents the diffusion of oxygen into the underlying material. This barrier is in contrast to iron or plain carbon steels, where the oxygen migrates into the underlying material and causes rusting.

The passivation can be enhanced by short contact with oxidizing acids like nitric acid. Passivated chromium is stable against acids. The opposite effect can be achieved by treatment with a strong reducing agent that destroys the protective oxide layer on the metal. Chromium metal treated in this way readily dissolves in weak acids.

Chromium, unlike metals such as iron and nickel, does not suffer from hydrogen embrittlement. However, it does suffer from nitrogen embrittlement, reacting with nitrogen from air and forming brittle nitrides at the high temperatures necessary to work the metal parts.

Occurrence

Chromium is the 24th most abundant element in Earth's crust with an average concentration of 100 ppm. Chromium compounds are found in the environment, due to erosion of chromium-containing rocks and can be distributed by volcanic eruptions. The concentrations range in soil is between 1 and 3000 mg/kg, in sea water 5 to 800 µg/liter, and in rivers and lakes 26 µg/liter to 5.2 mg/liter. Chromium is mined as chromite (FeCr_2O_4) ore. About two-fifths of the chromite ores and concentrates in the world are produced in South Africa, while Kazakhstan, India, Russia, and Turkey are also substantial producers. Untapped chromite deposits are plentiful, but geographically concentrated in Kazakhstan and southern Africa.

Although rare, deposits of native chromium exist. The Udachnaya Pipe in Russia produces samples of the native metal. This mine is a kimberlite pipe, rich in diamonds, and the reducing environment helped produce both elemental chromium and diamond.

The relation between Cr(III) and Cr(VI) strongly depends on pH and oxidative properties of the location, but in most cases, the Cr(III) is the dominating species, although in some areas the ground water can contain up to 39 µg/liter of total chromium of which 30 µg/liter is present as Cr(VI).

Isotopes

Naturally occurring chromium is composed of three stable isotopes; ^{52}Cr , ^{53}Cr and ^{54}Cr with ^{52}Cr being the most abundant (83.789% natural abundance). 19 radioisotopes have been characterized with the most stable being ^{50}Cr with a half-life of (more than) 1.8×10^{17} years, and ^{51}Cr with a half-life of 27.7 days. All of the remaining radioactive isotopes have half-lives that are less than 24 hours and the majority of these have half-lives that are less than 1 minute. This element also has 2 meta states.

^{53}Cr is the radiogenic decay product of ^{53}Mn . Chromium isotopic contents are typically combined with manganese isotopic contents and have found application in isotope geology.

Mn-Cr isotope ratios reinforce the evidence from ^{26}Al and ^{107}Pd for the early history of the solar system. Variations in $^{53}\text{Cr}/^{52}\text{Cr}$ and Mn/Cr ratios from several meteorites indicate an initial $^{53}\text{Mn}/^{55}\text{Mn}$ ratio that suggests Mn-Cr isotopic composition must result from in-situ decay of ^{53}Mn in differentiated planetary bodies. Hence ^{53}Cr provides additional evidence for nucleosynthetic processes immediately before coalescence of the solar system.

The isotopes of chromium range in atomic mass from 43 u (^{43}Cr) to 67 u (^{67}Cr). The primary decay mode before the most abundant stable isotope, ^{52}Cr , is electron capture and the primary mode after is beta decay. ^{53}Cr has been posited as a proxy for atmospheric oxygen concentration

Chromium(III)

A large number of chromium(III) compounds are known. Chromium(III) can be obtained by dissolving elemental chromium in acids like hydrochloric acid or sulfuric acid. The Cr^{3+} ion has a similar radius (63 pm) to the Al^{3+} ion (radius 50 pm), so they can replace each other in some compounds, such as in chrome alum and alum. When a trace amount of Cr^{3+} replaces Al^{3+} in corundum (aluminum oxide, Al_2O_3), the red-colored ruby is formed.

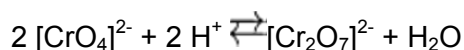
Chromium(III) ions tend to form octahedral complexes. The colors of these complexes is determined by the ligands attached to the Cr center. The commercially available chromium(III) chloride hydrate is the dark green complex $[\text{CrCl}_2(\text{H}_2\text{O})_4]\text{Cl}$. Closely related compounds have different colors: pale green $[\text{CrCl}(\text{H}_2\text{O})_5]\text{Cl}_2$ and the violet $[\text{Cr}(\text{H}_2\text{O})_6]\text{Cl}_3$.

If water-free green chromium(III) chloride is dissolved in water then the green solution turns violet after some time, due to the substitution of water by chloride in the inner coordination sphere. This kind of reaction is also observed with solutions of chrome alum and other water-soluble chromium(III) salts.

Chromium(III) hydroxide ($\text{Cr}(\text{OH})_3$) is amphoteric, dissolving in acidic solutions to form $[\text{Cr}(\text{H}_2\text{O})_6]^{3+}$, and in basic solutions to form $[\text{Cr}(\text{OH})_6]^{3-}$. It is dehydrated by heating to form the green chromium(III) oxide (Cr_2O_3), which is the stable oxide with a crystal structure identical to that of corundum.

Chromium(VI)

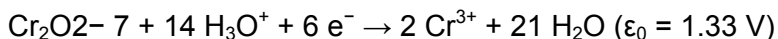
Chromium(VI) compounds are powerful oxidants at low or neutral pH. Most important are chromate anion (CrO_4^{2-}) and dichromate ($\text{Cr}_2\text{O}_7^{2-}$) anions, which exist in equilibrium:



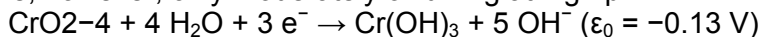
Chromium(VI) halides are known also and include the hexafluoride CrF_6 and chromyl chloride (CrO_2Cl_2).

Sodium chromate is produced industrially by the oxidative roasting of chromite ore with calcium or sodium carbonate. The dominant species is therefore, by the law of mass action, determined by the pH of the solution. The change in equilibrium is visible by a change from yellow (chromate) to orange (dichromate), such as when an acid is added to a neutral solution of potassium chromate. At yet lower pH values, further condensation to more complex oxyanions of chromium is possible.

Both the chromate and dichromate anions are strong oxidizing reagents at low pH:
Sodium chromate (Na_2CrO_4)



They are, however, only moderately oxidizing at high pH:



Chromium(VI) compounds in solution can be detected by adding an acidic hydrogen peroxide solution. The unstable dark blue chromium(VI) peroxide (CrO_5) is formed, which can be stabilized as an ether adduct $\text{CrO}_5 \cdot \text{OR}_2$.

Chromic acid has the hypothetical formula H_2CrO_4 . It is a vaguely described chemical, despite many well-defined chromates and dichromates are known. The dark red chromium(VI) oxide CrO_3 , the acid anhydride of chromic acid, is sold industrially as "chromic acid". It can be produced by mixing sulfuric acid with dichromate, and is a strong oxidizing agent.

Chromium(V) and chromium(IV)

The oxidation state +5 is only realized in few compounds but are intermediates in many reactions involving oxidations by chromate. The only binary compound is the volatile chromium(V) fluoride (CrF_5). This red solid has a melting point of 30°C and a boiling point of 117°C . It can be synthesized by treating chromium metal with fluorine at 400°C and 200 bar pressure. The peroxochromate(V) is another example of the +5 oxidation state. Potassium peroxochromate ($\text{K}_3[\text{Cr}(\text{O}_2)_4]$) is made by reacting potassium chromate with hydrogen peroxide at low temperatures. This red brown compound is stable at room temperature but decomposes spontaneously at $150\text{--}170^\circ\text{C}$.

Compounds of chromium(IV) (in the +4 oxidation state) are slightly more common than those of chromium(V). The tetrahalides, CrF_4 , CrCl_4 , and CrBr_4 , can be produced by treating the trihalides (CrX_3) with the corresponding halogen at elevated temperatures. Such compounds are susceptible to disproportionation reactions and are not stable in water.

Chromium(II)

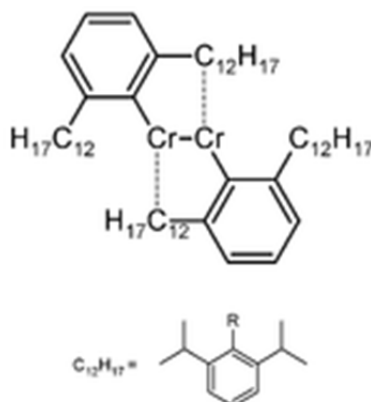
Many chromium(II) compounds are known, including the water-stable chromium(II) chloride, CrCl_2 , which can be made by reduction of chromium(III) chloride with zinc. The resulting bright blue solution is only stable at neutral pH. Many chromous carboxylates are also known, most famously, the red chromous acetate ($\text{Cr}_2(\text{O}_2\text{CCH}_3)_4$), which features a quadruple bond.

Chromium(I)

Most Cr(I) compounds are obtained by oxidation of electron-rich, octahedral Cr(0) complexes. Other Cr(I) complexes contain cyclopentadienyl ligands. As verified by X-ray diffraction, a Cr-Cr quintuple bond (length $183.51(4) \text{ pm}$) has also been described. Extremely bulky monodentate ligands stabilize this compound by shielding the quintuple bond from further reactions.

Chromium(0)

Many chromium(0) compounds are known. Most are derivatives of chromium hexacarbonyl or bis(benzene)chromium.



Chromium compound determined experimentally to contain a Cr-Cr quintuple bond

What are EPA's Drinking Water Regulations for Chromium (total)?

EPA has a drinking water standard of 0.1 milligrams per liter (mg/L) or 100 parts per billion (ppb) for total chromium, which includes all forms of chromium including chromium-6. Water systems are required to test for total chromium. The current standard is based on potential adverse dermatological effects over many years, such as allergic dermatitis (skin reactions). EPA regularly re-evaluates drinking water standards and, based on new science on chromium-6, began a rigorous and comprehensive review of its health effects in 2008.

Is Total Chromium or Chromium-6 in Drinking Water a Health Concern?

The current federal drinking water standard for total chromium is 0.1 mg/L or 100 ppb. Chromium-6 and chromium-3 are covered under the total chromium drinking water standard because these forms of chromium can convert back and forth in water and in the human body, depending on environmental conditions. Measuring just one form may not capture all of the chromium that is present. In order to ensure that the greatest potential risk is addressed, EPA's regulation assumes that a measurement of total chromium is 100 percent chromium-6, the more toxic form. If tap water from a public water system exceeds this federal standard, consumers will be notified.

The MCL for total chromium was established in 1991 and is based on the best available science at the time which indicated that continued exposure to chromium-6 could result in allergic dermatitis (skin reactions). EPA is now reviewing data from a 2008 long-term animal study by the Department of Health and Human Service's National Toxicology Program, which suggested that chromium-6 may be a human carcinogen if ingested. When the review is completed, EPA will consider this and other information to determine whether the drinking water standard for total chromium needs to be revised.

If EPA decides to revise the Regulation that includes Chromium-6 in Drinking Water, what is the process the agency will follow?

Prior to EPA making any decisions about revising the chromium drinking water regulation, EPA must issue its final human health assessment for chromium-6. EPA will carefully review the final assessment and consider all other relevant information to determine if a new drinking water regulation for chromium-6 or a revision to the current total chromium standard is warranted.

How does Chromium get into my Drinking Water?

The most common forms of chromium that occur in natural waters in the environment are chromium-3 and chromium-6. Chromium-3 and chromium-6 occur naturally in the environment, and are present in water from the erosion of chromium deposits found in rocks and soils. Chromium-6 is also produced by industrial processes and manufacturing activities including discharges from steel and pulp mills among others. At many locations, chromium compounds have been released to the environment via leakage, poor storage, or improper disposal practices. Chromium compounds are very persistent in water as sediments.

A federal law called the Emergency Planning and Community Right to Know Act requires facilities in certain industries, which manufacture, process, or use significant amounts of toxic chemicals, to report annually on their releases of these chemicals. For more information on the uses and releases of chemicals in your state, contact the community right-to-know hotline at (800) 424-9346.

How will I know if there is Chromium in my Drinking Water?

Your public water system's annual water quality report will provide information if total chromium is detected in the drinking water it delivers. The water quality report is sent to customers by July 1 of each year and may also be found on your public water system's website. Some water utilities have conducted monitoring specifically for chromium-6. Contact your public water system to find out if this information is available.

Consumers served by private wells can have their water tested by a state certified laboratory. You can find information on how to sample for chromium-6 and where to send samples by contacting your state water laboratory certification officer.

What should I do if I am concerned about the Presence of Chromium-6 in my Drinking Water while EPA is reviewing the Science and the Regulation?

If you remain concerned after finding out more about the chromium-6 levels in your drinking water, you may consider taking additional steps.

Can home treatment devices remove chromium-6?

Some home treatment devices are certified by organizations to remove chromium-6. Two certification organizations are: NSF International and the Water Quality Association. These certification programs are based on current drinking water standards and home treatment devices are only certified to remove chromium-6 to either 50 or 100 parts per billion. Contact the device's manufacturer for specific information about how effective the product is, given your water and treatment goal. Your public water system's water quality report and your water system's staff can help you understand the characteristics of your water.

If you choose to use a home treatment device, it is very important to follow the manufacturer's operation and maintenance instructions carefully in order to make sure the device works properly.

Consumers should be aware that the current EPA drinking water standard for chromium requires that public water systems provide drinking water that does not exceed a total chromium concentration of 100 ppb.

Can I avoid exposure to chromium-6 if I only Drink Bottled Water? (Is there Chromium-6 in bottled water?)

The Food and Drug Administration (FDA) establishes standards for bottled water and has adopted EPA's total chromium standard of 100 ppb. Contact bottled water manufacturers for specific information about levels of chromium-6 in their products.

Copper - Inorganic Contaminant 1.3 mg/L Water MCLG

What are Copper's Health Effects?

Some people who drink water containing copper in excess of the action level may, with short term exposure, experience gastrointestinal distress, and with long-term exposure may experience liver or kidney damage. People with Wilson's Disease should consult their personal doctor if the amount of copper in their water exceeds the action level.

This health effects language is not intended to catalog all possible health effects for copper. Rather, it is intended to inform consumers of some of the possible health effects associated with copper in drinking water when the rule was finalized.



What are EPA's Drinking Water Regulations for Copper?

In 1974, Congress passed the Safe Drinking Water Act. This law requires EPA to determine the level of contaminants in drinking water at which no adverse health effects are likely to occur. These non-enforceable health goals, based solely on possible health risks and exposure over a lifetime with an adequate margin of safety, are called maximum contaminant level goals (MCLG). Contaminants are any physical, chemical, biological or radiological substances or matter in water.

The MCLG for copper is 1.3 mg/L or 1.3 ppm. EPA has set this level of protection based on the best available science to prevent potential health problems.

For most contaminants, EPA sets an enforceable regulation called a maximum contaminant level (MCL) based on the MCLG. MCLs are set as close to the MCLGs as feasible, considering cost, benefits and the ability of public water systems to detect and remove contaminants using suitable treatment technologies. However, because copper contamination of drinking water often results from corrosion of the plumbing materials belonging to water system customers, EPA established a treatment technique rather than an MCL for copper.

A treatment technique is an enforceable procedure or level of technological performance which water systems must follow to ensure control of a contaminant. The treatment technique regulation for copper (referred to as the Lead and Copper rule) requires water systems to control the corrosivity of the water. The regulation also requires systems to collect tap samples from sites served by the system that are more likely to have plumbing materials containing lead. If more than 10 percent of tap water samples exceed the copper action level of 1.3 milligrams per Liter (mg/L), water systems must take additional steps to reduce corrosiveness.

EPA promulgated the Lead and Copper Rule in 1991, and revised the regulation in 2000 and in 2007. States may set a more stringent regulation for copper in drinking water than EPA.

How does Copper get into my Drinking Water?

The major sources of copper in drinking water are corrosion of household plumbing systems; and erosion of natural deposits. Copper enters the water (“leaches”) through contact with the plumbing. Copper leaches into water through corrosion – a dissolving or wearing away of metal caused by a chemical reaction between water and your plumbing. Copper can leach into water primarily from pipes, but fixtures and faucets (brass), and fittings can also be a source. The amount of copper in your water also depends on the types and amounts of minerals in the water, how long the water stays in the pipes, the amount of wear in the pipes, the water’s acidity and its temperature.

How will I know if Copper is in my Drinking Water?

If you are concerned about copper in your drinking water, have the water tested for copper by a certified laboratory. (Lists are available from your state or local drinking water authority.) Since you cannot see, taste, or smell copper dissolved in water, testing is the only sure way of telling whether there are harmful quantities of lead in your drinking water. You should be particularly suspicious if your home has copper pipes. If you see signs of corrosion (frequent leaks, rust-colored water, stained dishes or laundry, or if your non-plastic plumbing is less than five years old. Your water supplier may have useful information, including whether the service connector used in your home or area is made of copper. Testing is especially important in high-rise buildings where flushing might not work.

If your water comes from a household well, check with your health department or local water systems that use ground water for information on contaminants of concern in your area.

How will Copper be removed from my Drinking Water?

The following treatment method(s) have proven to be effective for removing copper to below the action level of 1.3 mg/L or 1.3 ppm: corrosion control.

How do I learn more about my Drinking Water?

EPA strongly encourages people to learn more about their drinking water, and to support local efforts to protect the supply of safe drinking water and upgrade the community water system. Your water bill or telephone book’s government listings are a good starting point for local information.

Contact your water utility. EPA requires all community water systems to prepare and deliver an annual consumer confidence report (CCR) (sometimes called a water quality report) for their customers by July 1 of each year. If your water provider is not a community water system, or if you have a private water supply, request a copy from a nearby community water system.

Copper Explained

Copper is a chemical element with the symbol **Cu** (from Latin: *cuprum*) and atomic number 29. It is a ductile metal with very high thermal and electrical conductivity. Pure copper is soft and malleable; a freshly exposed surface has a reddish-orange color. It is used as a conductor of heat and electricity, a building material, and a constituent of various metal alloys.

The metal and its alloys have been used for thousands of years. In the Roman era, copper was principally mined on Cyprus, hence the origin of the name of the metal as *cuprium* (metal of Cyprus), later shortened to *cuprum*.

Its compounds are commonly encountered as copper(II) salts, which often impart blue or green colors to minerals such as turquoise and have been widely used historically as pigments.

Architectural structures built with copper corrode to give green verdigris (or patina). Decorative art prominently features copper, both by itself and as part of pigments.

Copper(II) ions are water-soluble, where they function at low concentration as bacteriostatic substances, fungicides, and wood preservatives. In sufficient amounts, they are poisonous to higher organisms; at lower concentrations it is an essential trace nutrient to all higher plant and animal life. The main areas where copper is found in animals are liver, muscle and bone.

Characteristics

Physical

Copper, silver and gold are in group 11 of the periodic table, and they share certain attributes: they have one s-orbital electron on top of a filled d-electron shell and are characterized by high ductility and electrical conductivity. The filled d-shells in these elements do not contribute much to the interatomic interactions, which are dominated by the s-electrons through metallic bonds. Contrary to metals with incomplete d-shells, metallic bonds in copper are lacking a covalent character and are relatively weak. This explains the low hardness and high ductility of single crystals of copper. At the macroscopic scale, introduction of extended defects to the crystal lattice, such as grain boundaries, hinders flow of the material under applied stress thereby increasing its hardness. For this reason, copper is usually supplied in a fine-grained polycrystalline form, which has greater strength than monocrystalline forms.

The low hardness of copper partly explains its high electrical (59.6×10^6 S/m) and thus also high thermal conductivity, which are the second highest among pure metals at room temperature. This is because the resistivity to electron transport in metals at room temperature mostly originates from scattering of electrons on thermal vibrations of the lattice, which are relatively weak for a soft metal. The maximum permissible current density of copper in open air is approximately 3.1×10^6 A/m² of cross-sectional area, above which it begins to heat excessively. As with other metals, if copper is placed against another metal, galvanic corrosion will occur.

Together with caesium and gold (both yellow), copper is one of only three elemental metals with a natural color other than gray or silver. Pure copper is orange-red and acquires a reddish tarnish when exposed to air. The characteristic color of copper results from the electronic transitions between the filled 3d and half-empty 4s atomic shells – the energy difference between these shells is such that it corresponds to orange light. The same mechanism accounts for the yellow color of gold and caesium.

Chemical

Copper forms a rich variety of compounds with oxidation states +1 and +2, which are often called *cuprous* and *cupric*, respectively. It does not react with water, but it slowly reacts with atmospheric oxygen forming a layer of brown-black copper oxide. In contrast to the oxidation of iron by wet air, this oxide layer stops the further, bulk corrosion. A green layer of verdigris (copper carbonate) can often be seen on old copper constructions, such as the Statue of Liberty, the largest copper statue in the world built using repoussé and chasing. Hydrogen sulfides and sulfides react with copper to form various copper sulfides on the surface. In the latter case, the copper corrodes, as is seen when copper is exposed to air containing sulfur compounds.

Oxygen-containing ammonia solutions give water-soluble complexes with copper, as do oxygen and hydrochloric acid to form copper chlorides and acidified hydrogen peroxide to form copper(II) salts. Copper(II) chloride and copper compropionate to form copper(I) chloride.

Isotopes

There are 29 isotopes of copper. ^{63}Cu and ^{65}Cu are stable, with ^{63}Cu comprising approximately 69% of naturally occurring copper; they both have a spin of 3/2. The other isotopes are radioactive, with the most stable being ^{67}Cu with a half-life of 61.83 hours. Seven metastable isotopes have been characterized, with $^{68\text{m}}\text{Cu}$ the longest-lived with a half-life of 3.8 minutes. Isotopes with a mass number above 64 decay by β^- , whereas those with a mass number below 64 decay by β^+ . ^{64}Cu , which has a half-life of 12.7 hours, decays both ways.

^{62}Cu and ^{64}Cu have significant applications. ^{64}Cu is a radiocontrast for X-ray imaging, and complexed with a chelate can be used for treating cancer. ^{62}Cu is used in ^{62}Cu -PTSM that is a radioactive tracer for positron emission tomography.

Occurrence

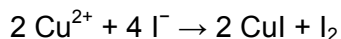
Copper can be found as either native copper or as part of minerals. Native copper is a polycrystal, with the largest described single crystal measuring 4.4×3.2×3.2 cm. The largest mass of elemental copper weighed 420 tons and was found in 1857 on the Keweenaw Peninsula in Michigan, US. There are many examples of copper-containing minerals: chalcopyrite and chalcocite are copper sulfides, azurite and malachite are copper carbonates and cuprite is a copper oxide. Copper is present in the Earth's crust at a concentration of about 50 parts per million (ppm), and is also synthesized in massive stars.

Compounds

Binary Compounds

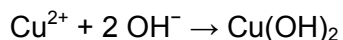
As for other elements, the simplest compounds of copper are binary compounds, i.e. those containing only two elements. The principal ones are the oxides, sulfides and halides. Both cuprous and cupric oxides are known. Among the numerous copper sulfides, important examples include copper(I) sulfide and copper(II) sulfide.

The cuprous halides with chlorine, bromine, and iodine are known, as are the cupric halides with fluorine, chlorine, and bromine. Attempts to prepare copper(II) iodide give cuprous iodide and iodine.

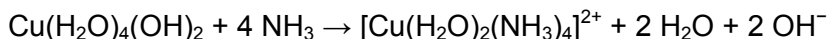


Coordination Chemistry

Copper, like all metals, forms coordination complexes with ligands. In aqueous solution, copper(II) exists as $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$. This complex exhibits the fastest water exchange rate (speed of water ligands attaching and detaching) for any transition metal aquo complex. Adding aqueous sodium hydroxide causes the precipitation of light blue solid copper(II) hydroxide. A simplified equation is:



Aqueous ammonia results in the same precipitate. Upon adding excess ammonia, the precipitate dissolves, forming tetraamminecopper(II):



Many other oxyanions form complexes; these include copper(II) acetate, copper(II) nitrate, and copper(II) carbonate. Copper(II) sulfate forms a blue crystalline pentahydrate, which is the most familiar copper compound in the laboratory. It is used in a fungicide called the Bordeaux mixture.

Polyols, compounds containing more than one alcohol functional group, generally interact with cupric salts. For example, copper salts are used to test for reducing sugars. Specifically, using Benedict's reagent and Fehling's solution the presence of the sugar is signaled by a color change from blue Cu(II) to reddish copper(I) oxide. Schweizer's reagent and related complexes with ethylenediamine and other amines dissolve cellulose. Amino acids form very stable chelate complexes with copper(II). Many wet-chemical tests for copper ions exist, one involving potassium ferrocyanide, which gives a brown precipitate with copper(II) salts.

Organocopper Chemistry

Compounds that contain a carbon-copper bond are known as organocopper compounds. They are very reactive towards oxygen to form copper(I) oxide and have many uses in chemistry. They are synthesized by treating copper(I) compounds with Grignard reagents, terminal alkynes or organolithium reagents; in particular, the last reaction described produces a Gilman reagent. These can undergo substitution with alkyl halides to form coupling products; as such, they are important in the field of organic synthesis.

Copper(I) acetylide is highly shock-sensitive but is an intermediate in reactions such as the Cadiot-Chodkiewicz coupling and the Sonogashira coupling. Conjugate addition to enones and carbocupration of alkynes can also be achieved with organocopper compounds. Copper(I) forms a variety of weak complexes with alkenes and carbon monoxide, especially in the presence of amine ligands.

Copper (III) and Copper (IV)

Copper(III) is most characteristically found in oxides. A simple example is potassium cuprate, KCuO_2 , a blue-black solid. The best studied copper(III) compounds are the cuprate superconductors. Yttrium barium copper oxide ($\text{YBa}_2\text{Cu}_3\text{O}_7$) consists of both Cu(II) and Cu(III) centers. Like oxide, fluoride is a highly basic anion and is known to stabilize metal ions in high oxidation states. Indeed, both copper(III) and even copper(IV) fluorides are known, K_3CuF_6 and Cs_2CuF_6 , respectively.

Some copper proteins form oxo complexes, which also feature copper(III). With di- and tripeptides, purple-colored copper(III) complexes are stabilized by the deprotonated amide ligands.

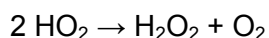
Complexes of copper(III) are also observed as intermediates in reactions of organocopper compounds.

Biological Role

Rich sources of copper include oysters, beef and lamb liver, Brazil nuts, blackstrap molasses, cocoa, and black pepper. Good sources include lobster, nuts and sunflower seeds, green olives, avocados, and wheat bran.

Copper proteins have diverse roles in biological electron transport and oxygen transportation, processes that exploit the easy interconversion of Cu(I) and Cu(II). The biological role for copper commenced with the appearance of oxygen in earth's atmosphere. The protein hemocyanin is the oxygen carrier in most mollusks and some arthropods such as the horseshoe crab (*Limulus polyphemus*). Because hemocyanin is blue, these organisms have blue blood, not the red blood found in organisms that rely on hemoglobin for this purpose. Structurally related to hemocyanin are the laccases and tyrosinases. Instead of reversibly binding oxygen, these proteins hydroxylate substrates, illustrated by their role in the formation of lacquers.

Copper is also a component of other proteins associated with the processing of oxygen. In cytochrome c oxidase, which is required for aerobic respiration, copper and iron cooperate in the reduction of oxygen. Copper is also found in many superoxide dismutases, proteins that catalyze the decomposition of superoxides, by converting it (by disproportionation) to oxygen and hydrogen peroxide:



Several copper proteins, such as the "blue copper proteins", do not interact directly with substrates, hence they are not enzymes. These proteins relay electrons by the process called electron transfer.

Photosynthesis functions by an elaborate electron transport chain within the thylakoid membrane. A central "link" in this chain is plastocyanin, a blue copper protein.

Dietary Needs

Copper is an essential trace element in plants and animals, but not some microorganisms. The human body contains copper at a level of about 1.4 to 2.1 mg per kg of body mass. Stated differently, the RDA for copper in normal healthy adults is quoted as 0.97 mg/day and as 3.0 mg/day. Copper is absorbed in the gut, then transported to the liver bound to albumin. After processing in the liver, copper is distributed to other tissues in a second phase.

Copper transport here involves the protein ceruloplasmin, which carries the majority of copper in blood. Ceruloplasmin also carries copper that is excreted in milk, and is particularly well-absorbed as a copper source. Copper in the body normally undergoes enterohepatic circulation (about 5 mg a day, vs. about 1 mg per day absorbed in the diet and excreted from the body), and the body is able to excrete some excess copper, if needed, via bile, which carries some copper out of the liver that is not then reabsorbed by the intestine.

Copper-based Disorders

Because of its role in facilitating iron uptake, copper deficiency can produce anemia-like symptoms, neutropenia, bone abnormalities, hypopigmentation, impaired growth, increased incidence of infections, osteoporosis, hyperthyroidism, and abnormalities in glucose and cholesterol metabolism. Conversely, Wilson's disease causes an accumulation of copper in body tissues.

Severe deficiency can be found by testing for low plasma or serum copper levels, low ceruloplasmin, and low red blood cell superoxide dismutase levels; these are not sensitive to marginal copper status. The "cytochrome c oxidase activity of leucocytes and platelets" has been stated as another factor in deficiency, but the results have not been confirmed by replication.

Cyanide - Inorganic Contaminant 0.2 mg/L Water MCL

Cyanide is a carbon-nitrogen chemical unit which combines with many organic and inorganic compounds.

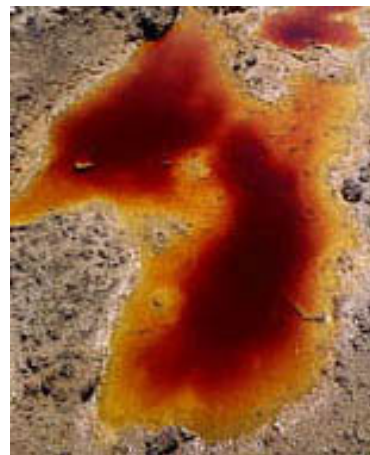
Uses for Cyanide.

The most commonly used form, hydrogen cyanide, is mainly used to make compounds and other synthetic fibers and resins.

What are Cyanide's Health Effects?

Some people who drink water containing cyanide well in excess of the maximum contaminant level (MCL) for many years could experience nerve damage or problems with their thyroid.

This health effects language is not intended to catalog all possible health effects for cyanide. Rather, it is intended to inform consumers of some of the possible health effects associated with cyanide in drinking water when the rule was finalized.



What are EPA's Drinking Water Regulations for Cyanide?

In 1974, Congress passed the Safe Drinking Water Act. This law requires EPA to determine the level of contaminants in drinking water at which no adverse health effects are likely to occur. These non-enforceable health goals, based solely on possible health risks and exposure over a lifetime with an adequate margin of safety, are called maximum contaminant level goals (MCLG). Contaminants are any physical, chemical, biological or radiological substances or matter in water.

The MCLG for cyanide is 0.2 mg/L or 200 ppb. EPA has set this level of protection based on the best available science to prevent potential health problems. EPA has set an enforceable regulation for cyanide, called a maximum contaminant level (MCL), at 0.2 mg/L or 200 ppb. MCLs are set as close to the health goals as possible, considering cost, benefits and the ability of public water systems to detect and remove contaminants using suitable treatment technologies. In this case, the MCL equals the MCLG, because analytical methods or treatment technology do not pose any limitation.

The Phase V Rule, the regulation for cyanide, became effective in 1994. The Safe Drinking Water Act requires EPA to periodically review the national primary drinking water regulation for each contaminant and revise the regulation, if appropriate. EPA reviewed cyanide as part of the Six Year Review and determined that the 0.2 mg/L or 200 ppb MCLG and 0.2 mg/L or 200 ppb MCL for cyanide are still protective of human health.

States may set more stringent drinking water MCLGs and MCLs for cyanide than EPA.

How does Cyanide get into my Drinking Water?

The major source of cyanide in drinking water is discharge from industrial chemical factories. A federal law called the Emergency Planning and Community Right to Know Act (EPCRA) requires facilities in certain industries, which manufacture, process, or use significant amounts of toxic chemicals, to report annually on their releases of these chemicals. For more information on the uses and releases of chemicals in your state, contact the Community Right-to-Know Hotline: (800) 424-9346.

How will I know if Cyanide is in my Drinking Water?

When routine monitoring indicates that cyanide levels are above the MCL, your water supplier must take steps to reduce the amount of cyanide so that it is below that level. Water suppliers must notify their customers as soon as practical, but no later than 30 days after the system learns of the violation. Additional actions, such as providing alternative drinking water supplies, may be required to prevent serious risks to public health.

If your water comes from a household well, check with your health department or local water systems that use ground water for information on contaminants of concern in your area.

How will Cyanide be Removed from my Drinking Water?

The following treatment method(s) have proven to be effective for removing cyanide to below 0.2 mg/L or 200 ppb: granular activated carbon in combination with packed tower aeration.

How do I learn more about my Drinking Water?

EPA strongly encourages people to learn more about their drinking water, and to support local efforts to protect the supply of safe drinking water and upgrade the community water system. Your water bill or telephone book's government listings are a good starting point for local information.

Contact your water utility. EPA requires all community water systems to prepare and deliver an annual consumer confidence report (CCR) (sometimes called a water quality report) for their customers by July 1 of each year. If your water provider is not a community water system, or if you have a private water supply, request a copy from a nearby community water system.

Cyanide Explained

A **cyanide** is a chemical compound that contains the **cyano group**, $\text{-C}\equiv\text{N}$, which consists of a carbon atom triple-bonded to a nitrogen atom. Cyanides most commonly refer to salts of the anion CN^- , which is isoelectronic with carbon monoxide and with molecular nitrogen. Most cyanides are highly toxic.

Nomenclature and Etymology

In IUPAC nomenclature, organic compounds that have a $\text{-C}\equiv\text{N}$ functional group are called nitriles. Thus, nitriles are organic compounds. An example of a nitrile is CH_3CN , acetonitrile, also known as methyl cyanide. Nitriles usually do not release cyanide ions. A functional group with a hydroxyl and cyanide bonded to the same carbon is called cyanohydrin. Unlike nitriles, cyanohydrins do release hydrogen cyanide. In inorganic chemistry, salts containing the $\text{C}\equiv\text{N}^-$ ion are referred to as **cyanides**.

Occurrence and Reactions

Cyanides are produced by certain bacteria, fungi, and algae and are found in a number of plants. Cyanides are found, although in small amounts, in certain seeds and fruit stones, e.g., those of apple, mango, peach, and bitter almonds. In plants, cyanides are usually bound to sugar molecules in the form of cyanogenic glycosides and defend the plant against herbivores. Cassava roots (also called manioc), an important potato-like food grown in tropical countries (and the base from which tapioca is made), also contain cyanogenic glycosides.

Interstellar Medium

The cyanide radical $\text{CN}\cdot$ has been identified in interstellar space. The cyanide radical (called cyanogen) is used to measure the temperature of interstellar gas clouds.

Pyrolysis and Combustion Product

Hydrogen cyanide is produced by the combustion or pyrolysis of certain materials under oxygen-deficient conditions. For example, it can be detected in the exhaust of internal combustion engines and tobacco smoke. Certain plastics, especially those derived from acrylonitrile, release hydrogen cyanide when heated or burnt.

Coordination Chemistry

The cyanide anion is a ligand for many transition metals. The high affinities of metals for this anion can be attributed to its negative charge, compactness, and ability to engage in π -bonding.

Well-known complexes include:

- hexacyanides $[\text{M}(\text{CN})_6]^{3-}$ ($\text{M} = \text{Ti}, \text{V}, \text{Cr}, \text{Mn}, \text{Fe}, \text{Co}$), which are octahedral in shape;
- the tetracyanides, $[\text{M}(\text{CN})_4]^{2-}$ ($\text{M} = \text{Ni}, \text{Pd}, \text{Pt}$), which are square planar in their geometry;
- the dicyanides $[\text{M}(\text{CN})_2]^-$ ($\text{M} = \text{Cu}, \text{Ag}, \text{Au}$), which are linear in geometry.

The dye Prussian blue was first accidentally made around 1706, by heating substances containing iron and carbon and nitrogen. Prussian blue consists of an iron-containing compound called "ferrocyanide" ($[\text{Fe}(\text{CN})_6]^{4-}$) meaning "blue substance with iron", from Latin *ferrum* = "iron" and Greek *kyanos* = "(dark) blue". Prussian blue is the deep-blue pigment used in the making of blueprints.

The enzymes called hydrogenases contain cyanide ligands attached to iron in their active sites. The biosynthesis of cyanide in the $[\text{NiFe}]$ -hydrogenases proceeds from carbamoylphosphate, which converts to cysteinyl thiocyanate, the CN^- donor.

Organic Derivatives

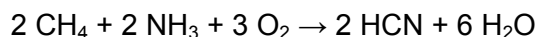
Because of the cyanide anion's high nucleophilicity, cyano groups are readily introduced into organic molecules by displacement of a halide group (e.g., the chloride on methyl chloride). In general, organic cyanides are called nitriles. Thus, CH_3CN can be called methyl cyanide but more commonly is referred to as acetonitrile. In organic synthesis, cyanide is a C-1 synthon; i.e., it can be used to lengthen a carbon chain by one, while retaining the ability to be functionalized.

$\text{RX} + \text{CN}^- \rightarrow \text{RCN} + \text{X}^-$ (nucleophilic substitution) followed by

1. $\text{RCN} + 2 \text{H}_2\text{O} \rightarrow \text{RCOOH} + \text{NH}_3$ (hydrolysis under reflux with mineral acid catalyst), or
2. $2 \text{RCN} + \text{LiAlH}_4 + (\text{second step}) 4 \text{H}_2\text{O} \rightarrow 2 \text{RCH}_2\text{NH}_2 + \text{LiAl}(\text{OH})_4$ (under reflux in dry ether, followed by addition of H_2O)

Manufacture

The principal process used to manufacture cyanides is the Andrussov process in which gaseous hydrogen cyanide is produced from methane and ammonia in the presence of oxygen and a platinum catalyst.



Gaseous hydrogen cyanide may be dissolved in aqueous sodium hydroxide solution to produce sodium cyanide.

Toxicity

Many cyanides are highly toxic. The cyanide anion is an inhibitor of the enzyme cytochrome c oxidase (also known as aa₃) in the fourth complex of the electron transport chain (found in the membrane of the mitochondria of eukaryotic cells). It attaches to the iron within this protein. The binding of cyanide to this cytochrome prevents transport of electrons from cytochrome c oxidase to oxygen. As a result, the electron transport chain is disrupted, meaning that the cell can no longer aerobically produce ATP for energy. Tissues that depend highly on aerobic respiration, such as the central nervous system and the heart, are particularly affected. This is an example of histotoxic hypoxia.

The most hazardous compound is hydrogen cyanide, which is a gas at ambient temperatures and pressure and can therefore be inhaled. For this reason, an air respirator supplied by an external oxygen source must be worn when working with hydrogen cyanide. Hydrogen cyanide is produced when a solution containing a labile cyanide is made acidic, because HCN is a weak acid. Alkaline solutions are safer to use because they do not evolve hydrogen cyanide gas. Hydrogen cyanide may be produced in the combustion of polyurethanes; for this reason, polyurethanes are not recommended for use in domestic and aircraft furniture. Oral ingestion of a small quantity of solid cyanide or a cyanide solution as little as 200 mg, or to airborne cyanide of 270 ppm is sufficient to cause death within minutes.

Organic nitriles do not readily release cyanide ions, and so have low toxicities. By contrast, compounds such as trimethylsilyl cyanide (CH₃)₃SiCN readily release HCN or the cyanide ion upon contact with water.

Antidote

Hydroxocobalamin reacts with cyanide to form cyanocobalamin, which can be safely eliminated by the kidneys. This method has the advantage of avoiding the formation of methemoglobin.

An older cyanide antidote kit included administration of three substances: amyl nitrite pearls (administered by inhalation), sodium nitrite, and sodium thiosulfate (administered by infusion). The goal of the antidote was to generate a large pool of ferric iron (Fe³⁺) to compete with cyanide cytochrome a₃ (so that cyanide will bind to the antidote rather than the enzyme). The nitrites oxidize hemoglobin to methemoglobin, which competes with cytochrome oxidase for the cyanide ion. Cyanmethemoglobin is formed and the cytochrome oxidase enzyme is restored. The major mechanism to remove the cyanide from the body is by enzymatic conversion to thiocyanate by the mitochondrial enzyme rhodanese. Thiocyanate is a relatively non-toxic molecule and is excreted by the kidneys. To accelerate this detoxification, sodium thiosulfate is administered to provide a sulfur donor for rhodanese, needed in order to produce thiocyanate.

Sensitivity

Minimum risk levels (MRLs) may not protect for delayed health effects or health effects acquired following repeated sublethal exposure, such as hypersensitivity, asthma, or bronchitis. MRLs may be revised after sufficient data accumulates (Toxicological Profile for Cyanide, U.S. Department of Health and Human Services, 2006).

Chemical Tests for Cyanide

Prussian Blue

Iron (II) sulfate is added to a solution suspected of containing cyanide, such as the filtrate from the sodium fusion test. The resulting mixture is acidified with mineral acid. The formation of Prussian blue is a positive result for cyanide.

Para-Benzoquinone in DMSO

A solution of *para*-benzoquinone in DMSO reacts with inorganic cyanide to form a cyanophenol, which is fluorescent. Illumination with a UV light gives a green/blue glow if the test is positive.

Copper and an Aromatic Amine

As used by fumigators to detect hydrogen cyanide, copper (II) salt and an aromatic amine such as benzidine is added to the sample; as an alternative to benzidine an alternative amine di-(4,4-*bis*-dimethylaminophenyl) methane can be used. A positive test gives a blue color. Copper (I) cyanide is poorly soluble. By sequestering the copper(I) the copper(II) is rendered a stronger oxidant. The copper, in a cyanide facilitated oxidation, converts the amine into a colored compound. The Nernst equation explains this process. Another good example of such chemistry is the way in which the saturated calomel reference electrode (SCE) works. The copper, in a cyanide-facilitated oxidation, converts the amine into a colored compound.

Pyridine-Barbituric Acid Colorimetry

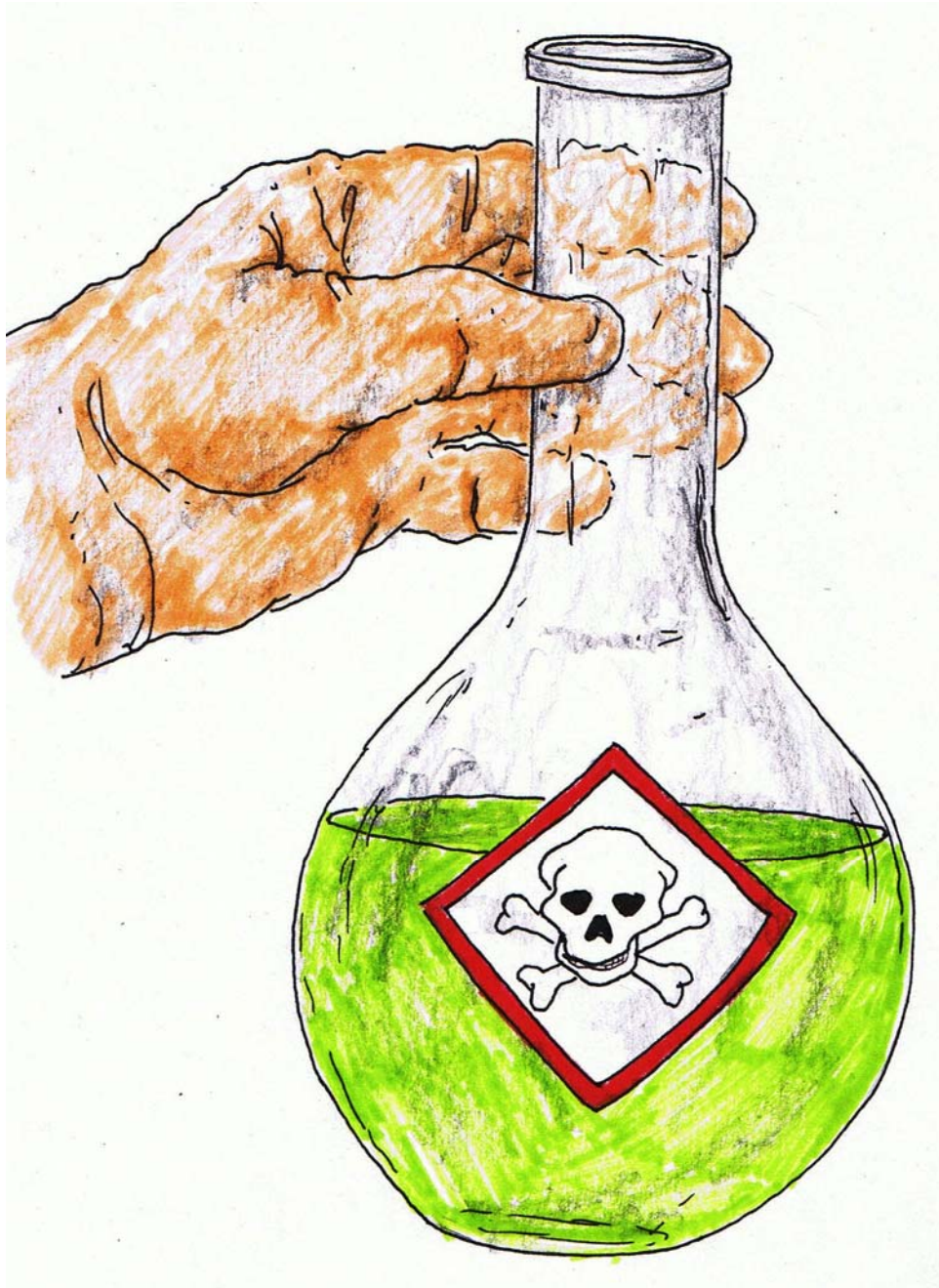
A sample containing inorganic cyanide is purged with air from a boiling acid solution into a basic absorber solution. The cyanide salt absorbed in the basic solution is buffered at pH 4.5 and then reacted with chlorine to form cyanogen chloride. The cyanogen chloride formed couples pyridine with barbituric acid to form a strongly colored red dye that is proportional to the cyanide concentration.

This colorimetric method following distillation is the basis for most regulatory methods (for instance EPA 335.4) used to analyze cyanide in water, wastewater, and contaminated soils. Distillation followed by colorimetric methods, however, have been found to be prone to interferences from thiocyanate, nitrate, thiosulfate, sulfite, and sulfide that can result in both positive and negative bias. It has been recommended by the USEPA (MUR March 12, 2007) that samples containing these compounds be analyzed by Gas-Diffusion Flow Injection Analysis — Amperometry.

Gas Diffusion Flow Injection Analysis — Amperometry

Instead of distilling, the sample is injected into an acidic stream where the HCN formed is passed under a hydrophobic gas diffusion membrane that selectively allows only HCN to pass through. The HCN that passes through the membrane is absorbed into a basic carrier solution that transports the CN to an amperometric detector that accurately measures cyanide concentration with high sensitivity.

Sample pretreatment determined by acid reagents, ligands, or preliminary UV irradiation allow cyanide speciation of free cyanide, available cyanide, and total cyanide respectively. The relative simplicity of these flow injection analysis methods limit the interference experienced by the high heat of distillation and also prove to be cost effective since time consuming distillations are not required.



Fluoride. Many communities add fluoride to their drinking water to promote dental health. Each community makes its own decision about whether or not to add fluoride. The EPA has set an enforceable drinking water standard for fluoride of 4 mg/L (some people who drink water containing fluoride in excess of this level over many years could develop bone disease, including pain and tenderness of the bones). The EPA has also set a secondary fluoride standard of 2 mg/L to protect against dental fluorosis.

Fluoride - Inorganic Contaminant 4.0 mg/L Water MCL

Fluoride compounds are salts that form when the element, fluorine, combines with minerals in soil or rocks.

Uses for Fluoride.

Many communities add fluoride to their drinking water to promote dental health.

What are Fluoride's Health Effects?

Exposure to excessive consumption of fluoride over a lifetime may lead to increased likelihood of bone fractures in adults, and may result in effects on bone leading to pain and tenderness. Children aged 8 years and younger exposed to excessive amounts of fluoride have an increased chance of developing pits in the tooth enamel, along with a range of cosmetic effects to teeth.



This health effects language is not intended to catalog all possible health effects for fluoride. Rather, it is intended to inform consumers of some of the possible health effects associated with fluoride in drinking water.

What are EPA's Drinking Water Regulations for Fluoride?

In 1974, Congress passed the Safe Drinking Water Act. This law requires EPA to determine the level of contaminants in drinking water at which no adverse health effects are likely to occur. These non-enforceable health goals, based solely on possible health risks and exposure over a lifetime with an adequate margin of safety, are called maximum contaminant level goals (MCLG). Contaminants are any physical, chemical, biological or radiological substances or matter in water.

The MCLG for fluoride is 4.0 mg/L or 4.0 ppm. EPA has set this level of protection based on the best available science to prevent potential health problems. EPA has set an enforceable regulation for fluoride, called a maximum contaminant level (MCL), at 4.0 mg/L or 4.0 ppm. MCLs are set as close to the health goals as possible, considering cost, benefits and the ability of public water systems to detect and remove contaminants using suitable treatment technologies. In this case, the MCL equals the MCLG, because analytical methods or treatment technology do not pose any limitation.

EPA has also set a secondary standard (SMCL) for fluoride at 2.0 mg/L or 2.0 ppm. Secondary standards are non-enforceable guidelines regulating contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water. EPA recommends secondary standards to water systems but does not require systems to comply. However, states may choose to adopt them as enforceable standards.

Tooth discoloration and/or pitting is caused by excess fluoride exposures during the formative period prior to eruption of the teeth in children. The secondary standard of 2.0 mg/L is intended as a guideline for an upper bound level in areas which have high levels of naturally occurring fluoride. The level of the SMCL was set based upon a balancing of the beneficial effects of protection from tooth decay and the undesirable effects of excessive exposures leading to discoloration.

Fluoride is voluntarily added to some drinking water systems as a public health measure for reducing the incidence of cavities among the treated population.

The decision to fluoridate a water supply is made by the State or local municipality, and is not mandated by EPA or any other Federal entity. The Centers for Disease Control and Prevention (CDC) provides recommendations about the optimal levels of fluoride in drinking water in order to prevent tooth decay. Information about CDC's recommendations can be found at: <http://www.cdc.gov/fluoridation/>

States may set more stringent drinking water MCLGs and MCLs for fluoride than EPA.

The drinking water standards are currently under review. The Safe Drinking Water Act requires EPA to periodically review the national primary drinking water regulation for each contaminant and revise the regulation, if appropriate. In 2003 and as part of the first Six Year Review, EPA reviewed the drinking water standard for fluoride and found that new health and exposure data were available on orally ingested fluoride. EPA requested that the National Research Council (NRC) of the National Academies of Science (NAS) conduct a review of this data and in 2006, the NRC published their evaluation in a report entitled, Fluoride in Drinking Water: A Scientific Review of EPA's Standards. The NRC recommended that EPA update its fluoride risk assessment to include new data on health risks and better estimates of total exposure.

In March 2010 and as part of the second Six Year Review, the Agency indicated that the Office of Water was in the process of developing its health and exposure assessments to address the NRC's recommendations. The Agency finalized the risk and exposure assessments for fluoride in January 2011 and announced its intent to review the drinking water regulations for fluoride to determine whether revisions are appropriate.

How does Fluoride get into my Drinking Water?

Some fluoride compounds, such as sodium fluoride and fluorosilicates, dissolve easily into ground water as it moves through gaps and pore spaces between rocks. Most water supplies contain some naturally occurring fluoride. Fluoride also enters drinking water in discharge from fertilizer or aluminum factories. Also, many communities add fluoride to their drinking water to promote dental health.

A federal law called the Emergency Planning and Community Right to Know Act (EPCRA) requires facilities in certain industries, which manufacture, process, or use significant amounts of toxic chemicals, to report annually on their releases of these chemicals. For more information on the uses and releases of chemicals in your state, contact the Community Right-to-Know Hotline: (800) 424-9346.

How will I know if Fluoride is in my Drinking Water?

When routine monitoring indicates that fluoride levels are above the MCL, your water supplier must take steps to reduce the amount of fluoride so that it is below that level. Water suppliers must notify their customers as soon as practical, but no later than 30 days after the system learns of the violation. Additional actions, such as providing alternative drinking water supplies, may be required to prevent serious risks to public health.

If your water comes from a household or private well, check with your health department or local water systems that use ground water for information on contaminants of concern in your area.

How will Fluoride be removed from my Drinking Water?

The following treatment method(s) have proven to be effective for removing fluoride to below 4.0 mg/L or 4.0 ppm: distillation or reverse osmosis.

How do I learn more about my Drinking Water?

EPA strongly encourages people to learn more about their drinking water, and to support local efforts to protect the supply of safe drinking water and upgrade the community water system. Your water bill or telephone book's government listings are a good starting point for local information.

Contact your water utility. EPA requires all community water systems to prepare and deliver an annual consumer confidence report (CCR) (sometimes called a water quality report) for their customers by July 1 of each year. If your water provider is not a community water system, or if you have a private water supply, request a copy from a nearby community water system.

Fluoride Explained

Fluoride is the anion F^- , the reduced form of fluorine when as an ion and when bonded to another element. Inorganic fluorine containing compounds are called fluorides. Fluoride, like other halides, is a monovalent ion (-1 charge). Its compounds often have properties that are distinct relative to other halides. Structurally, and to some extent chemically, the fluoride ion resembles the hydroxide ion.

Occurrence

Solutions of inorganic fluorides in water contain F^- and bifluoride HF_2^- . Few inorganic fluorides are soluble in water without undergoing significant hydrolysis. In terms of its reactivity, fluoride differs significantly from chloride and other halides, and is more strongly solvated due to its smaller radius/charge ratio. Its closest chemical relative is hydroxide. When relatively unsolvated, fluoride anions are called "naked". Naked fluoride is a very strong lewis base. The presence of fluoride and its compounds can be detected by F NMR spectroscopy.

Natural Occurrence

Many fluoride minerals are known, but of paramount commercial importance are fluorite and fluorapatite.

Fluoride is usually found naturally in low concentration in drinking water and foods. The concentration in seawater averages 1.3 parts per million (ppm). Fresh water supplies generally contain between 0.01–0.3 ppm, whereas the ocean contains between 1.2 and 1.5 ppm. In some locations, the fresh water contains dangerously high levels of fluoride, leading to serious health problems.

Applications

Fluorides are pervasive in modern technology. Hydrofluoric acid is the fluoride synthesized on the largest scale. It is produced by treating fluoride minerals with sulfuric acid. Hydrofluoric acid and its anhydrous form hydrogen fluoride are used in the production of fluorocarbons and aluminum fluorides. Hydrofluoric acid has a variety of specialized applications, including its ability to dissolve glass.

Inorganic Chemicals

Fluoride salts are used in the manufacture of many inorganic chemicals, many of which contain fluoride covalently bonded to the metal or nonmetal in question. Some examples of these are:

- Cryolite (Na_3AlF_6) is a pesticide that can leave fluoride on agricultural commodities. Cryolite was originally utilized in the preparation of aluminum.
- Sulfuryl fluoride (SO_2F_2) is used as a pesticide and fumigant on agricultural crops. In 2010, the United States Environmental Protection Agency proposed to withdraw the use of sulfuryl fluoride on food. Sulfuryl fluoride releases fluoride when metabolized.
- Sulfur hexafluoride is an inert, nontoxic insulator gas that is used in electrical transformers and as a tracer gas in indoor air quality investigations.
- Uranium hexafluoride, although not ionic, is prepared from fluoride reagents. It is utilized in the separation of isotopes of uranium between the fissile isotope U-235 and the non-fissile isotope U-238 in preparation of nuclear reactor fuel and atomic bombs. This is due to the volatility of fluorides of uranium.

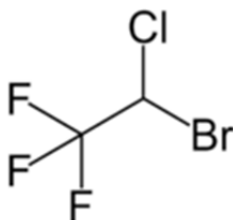
Organic Chemicals

Fluoride reagents are significant in synthetic organic chemistry. Organofluorine chemistry has produced many useful compounds over the last 50 years. Included in this area are polytetrafluoroethylene (Teflon), polychlorotrifluoroethylene (moisture barriers), efavirenz (pharmaceutical used for treatment of HIV), fluoxetine (an antidepressant), 5-fluorouracil (an anticancer drug), hydrochlorofluorocarbons and hydrofluorocarbons (refrigerants, blowing agents and propellants).

Due to the affinity of silicon for fluoride, and the ability of silicon to expand its coordination number, silyl ether protecting groups can be easily removed by the fluoride sources such as sodium fluoride and tetra-n-butylammonium fluoride (TBAF). This is quite useful for organic synthesis and the production of fine chemicals. The Si-F linkage is one of the strongest single bonds. In contrast, other silyl halides are easily hydrolyzed.

Cavity Prevention

Fluoride-containing compounds are used in topical and systemic fluoride therapy for preventing tooth decay. They are used for water fluoridation and in many products associated with oral hygiene. Originally, sodium fluoride was used to fluoridate water; hexafluorosilicic acid (H_2SiF_6) and its salt sodium hexafluorosilicate (Na_2SiF_6) are more commonly used additives, especially in the United States. The fluoridation of water is known to prevent tooth decay and is considered by the U.S. Centers for Disease Control and Prevention as "one of 10 great public health achievements of the 20th century". In some countries where large, centralized water systems are uncommon, fluoride is delivered to the populace by fluoridating table salt. Fluoridation of water has its critics (see Water fluoridation controversy).



Structure of halothane.

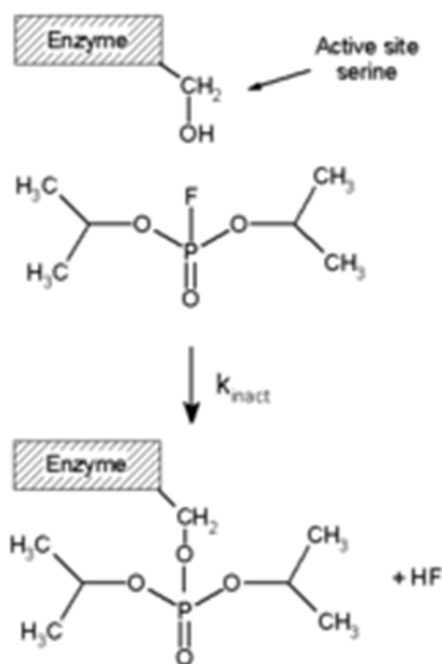
Biomedical Applications

Positron emission tomography is commonly carried out using fluoride-containing pharmaceuticals such as fluorodeoxyglucose, which is labeled with the radioactive isotope fluorine-18, which emits positrons when it decays into ^{18}O .

Numerous drugs contain fluorine including antipsychotics such as fluphenazine, HIV protease inhibitors such as tipranavir, antibiotics such as ofloxacin and trovafloxacin, and anesthetics such as halothane. Fluorine is incorporated in the drug structures to reduce drug metabolism, as the strong C-F bond resists deactivation in the liver by cytochrome P450 oxidases.

Fluoride salts are commonly used to inhibit the activity of phosphatases, such as serine/threonine phosphatases. Fluoride mimics the nucleophilic hydroxyl ion in these enzymes' active sites. Beryllium fluoride and aluminum fluoride are also used as phosphatase inhibitors, since these compounds are structural mimics of the phosphate group and can act as analogues of the transition state of the reaction.

Toxicology



Reaction of the irreversible inhibitor diisopropylfluorophosphate with a serine protease.

Fluoride-containing compounds are so diverse that it is not possible to generalize on their toxicity, which depends on their reactivity and structure, and in the case of salts, their solubility and ability to release fluoride ions.

Soluble fluoride salts, of which sodium fluoride is the most common, are mildly toxic but have resulted in both accidental and suicidal deaths from acute poisoning. While the minimum fatal dose in humans is not known, the lethal dose for most adult humans is estimated at 5 to 10 g (which is equivalent to 32 to 64 mg/kg elemental fluoride/kg body weight). However, a case of a fatal poisoning of an adult with 4 grams of sodium fluoride is documented, while a dose of 120 g sodium fluoride has been survived.

A toxic dose that may lead to adverse health effects is estimated at 3 to 5 mg/kg of elemental fluoride. For Sodium fluorosilicate (Na_2SiF_6), the median lethal dose (LD_{50}) orally in rats is 0.125 g/kg, corresponding to 12.5 g for a 100 kg adult. The fatal period ranges from 5 min to 12 hours. The mechanism of toxicity involves the combination of the fluoride anion with the calcium ions in the blood to form insoluble calcium fluoride, resulting in hypocalcemia; calcium is indispensable for the function of the nervous system, and the condition can be fatal. Treatment may involve oral administration of dilute calcium hydroxide or calcium chloride to prevent further absorption, and injection of calcium gluconate to increase the calcium levels in the blood. Hydrogen fluoride is more dangerous than salts such as NaF because it is corrosive and volatile, and can result in fatal exposure through inhalation or upon contact with the skin; calcium gluconate gel is the usual antidote.

In the higher doses used to treat osteoporosis, sodium fluoride can cause pain in the legs and incomplete stress fractures when the doses are too high; it also irritates the stomach, sometimes so severely as to cause ulcers. Slow-release and enteric-coated versions of sodium fluoride do not have gastric side effects in any significant way, and have milder and less frequent complications in the bones. In the lower doses used for water fluoridation, the only clear adverse effect is dental fluorosis, which can alter the appearance of children's teeth during tooth development; this is mostly mild and is unlikely to represent any real effect on aesthetic appearance or on public health.

Lead- Inorganic Contaminant 0.015 Water Action Level

The United States Environmental Protection Agency (EPA) regulates lead in drinking water to protect public health. Lead may cause health problems if present in public or private water supplies in amounts greater than the drinking water standard set by EPA.

What is Lead?

Lead is a toxic metal that was used for many years in products found in and around homes. Even at low levels, lead may cause a range of health effects including behavioral problems and learning disabilities. Children six years old and under are most at risk because this is when the brain is developing. The primary source of lead exposure for most children is lead-based paint in older homes. Lead in drinking water can add to that exposure.



Uses for Lead.

Lead is sometimes used in household plumbing materials or in water service lines used to bring water from the main to the home. A prohibition on lead in plumbing materials has been in effect since 1986. The lead ban, which was included in the 1986 Amendments of the Safe Drinking Water Act, states that only “lead free” pipe, solder, or flux may be used in the installation or repair of (1) public water systems, or (2) any plumbing in a residential or non-residential facility providing water for human consumption, which is connected to a public water system. But even “lead free” plumbing may contain traces of lead. The term “lead free” means that solders and flux may not contain more than 0.2 percent lead, and that pipes and pipe fittings may not contain more than 8.0 percent lead. Faucets and other end use devices must be tested and certified against the ANSI – NSF Standard 61 to be considered lead free.

What are Lead’s Health Effects?

Infants and children who drink water containing lead in excess of the action level could experience delays in their physical or mental development. Children could show slight deficits in attention span and learning abilities. Adults who drink this water over many years could develop kidney problems or high blood pressure.

This health effects language is not intended to catalog all possible health effects for lead. Rather, it is intended to inform consumers of the most significant and probable health effects, associated with lead in drinking water.

What are EPA’s Drinking Water Regulations for Lead?

In 1974, Congress passed the Safe Drinking Water Act. This law requires EPA to determine the level of contaminants in drinking water at which no adverse health effects are likely to occur with an adequate margin of safety. These non-enforceable health goals, based solely on possible health risks are called maximum contaminant level goals (MCLG). The MCLG for lead is zero.

EPA has set this level based on the best available science which shows there is no safe level of exposure to lead.

For most contaminants, EPA sets an enforceable regulation called a maximum contaminant level (MCL) based on the MCLG. MCLs are set as close to the MCLGs as possible, considering cost, benefits and the ability of public water systems to detect and remove contaminants using suitable treatment technologies. However, because lead contamination of drinking water often results from corrosion of the plumbing materials belonging to water system customers, EPA established a treatment technique rather than an MCL for lead.

A treatment technique is an enforceable procedure or level of technological performance which water systems must follow to ensure control of a contaminant. The treatment technique regulation for lead (referred to as the Lead and Copper rule) requires water systems to control the corrosivity of the water. The regulation also requires systems to collect tap samples from sites served by the system that are more likely to have plumbing materials containing lead.

If more than 10% of tap water samples exceed the lead action level of 15 parts per billion, then water systems are required to take additional actions including:

- Taking further steps optimize their corrosion control treatment (for water systems serving 50,000 people that have not fully optimized their corrosion control) .
- Educating the public about lead in drinking water and actions consumers can take to reduce their exposure to lead.
- Replacing the portions of lead service lines (lines that connect distribution mains to customers) under the water system's control.

EPA promulgated the Lead and Copper Rule in 1991 and revised the regulation in 2000 and 2007. States may set more stringent drinking water regulations than EPA.

How does Lead get into my Drinking Water?

The major sources of lead in drinking water are corrosion of household plumbing systems; and erosion of natural deposits. Lead enters the water ("leaches") through contact with the plumbing. Lead leaches into water through corrosion – a dissolving or wearing away of metal caused by a chemical reaction between water and your plumbing. Lead can leach into water from pipes, solder, fixtures and faucets (brass), and fittings. The amount of lead in your water also depends on the types and amounts of minerals in the water, how long the water stays in the pipes, the amount of wear in the pipes, the water's acidity and its temperature.

Although the main sources of exposure to lead are ingesting paint chips and inhaling dust, EPA estimates that 10 to 20 percent of human exposure to lead may come from lead in drinking water. Infants who consume mostly mixed formula can receive 40 to 60 percent of their exposure to lead from drinking water.

How will I know if Lead is in my Drinking Water?

Have your water tested for lead. A list of certified laboratory of labs are available from your state or local drinking water authority. Testing costs between \$20 and \$100. Since you cannot see, taste, or smell lead dissolved in water, testing is the only sure way of telling whether there are harmful quantities of lead in your drinking water. You should be particularly suspicious if your home has lead pipes (lead is a dull gray metal that is soft enough to be easily scratched with a house key) or if you see signs of corrosion (frequent leaks, rust-colored water). Your water supplier may have useful information, including whether the service connector used in your home or area is made of lead. Testing is especially important in high-rise buildings where flushing might not work.

If your water comes from a household well, check with your health department or local water systems that use ground water for information on contaminants of concern in your area.

How can I Reduce Lead in Drinking Water at Home?

Flush your pipes before drinking, and only use cold water for consumption. The more time water has been sitting in your home's pipes, the more lead it may contain. Anytime the water in a particular faucet has not been used for six hours or longer, "flush" your cold-water pipes by running the water until it becomes as cold as it will get.

This could take as little as five to thirty seconds if there has been recent heavy water use such as showering or toilet flushing. Otherwise, it could take two minutes or longer. Your water utility will inform you if longer flushing times are needed to respond to local conditions.

Use only water from the cold-water tap for drinking, cooking, and especially for making baby formula. Hot water is likely to contain higher levels of lead. The two actions recommended above are very important to the health of your family. They will probably be effective in reducing lead levels because most of the lead in household water usually comes from the plumbing in your house, not from the local water supply.

Should I be concerned about Lead in Drinking water in my child's school or child care facility?

Children spend a significant part of their days at school or in a child care facility. The faucets that provide water used for consumption, including drinking, cooking lunch, and preparing juice and infant formula, should be tested.

How do I learn more about my Drinking Water?

EPA strongly encourages people to learn more about their drinking water, and to support local efforts to protect and upgrade the supply of safe drinking water. Your water bill or telephone book's government listings are a good starting point for local information.

Contact your water utility. EPA requires all community water systems to prepare and deliver an annual consumer confidence report (CCR) (sometimes called a water quality report) for their customers by July 1 of each year. If your water provider is not a community water system, or if you have a private water supply, request a copy from a nearby community water system.

Lead Explained

Lead is a chemical element in the carbon group with symbol **Pb** (from Latin: *plumbum*) and atomic number 82. Lead is a soft, malleable poor metal. It is also counted as one of the heavy metals. Metallic lead has a bluish-white color after being freshly cut, but it soon tarnishes to a dull grayish color when exposed to air. Lead has a shiny chrome-silver luster when it is melted into a liquid.

Lead is used in building construction, lead-acid batteries, bullets and shot, weights, as part of solders, pewters, fusible alloys, and as a radiation shield. Lead has the highest atomic number of all of the stable elements, although the next higher element, bismuth, has a half-life that is so long (much longer than the age of the universe) that it can be considered stable. Its four stable isotopes have 82 protons, a magic number in the nuclear shell model of atomic nuclei.

Lead, at certain contact degrees, is a poisonous substance to animals, including humans. It damages the nervous system and causes brain disorders. Excessive lead also causes blood disorders in mammals. Like the element mercury, another heavy metal, lead is a neurotoxin that accumulates both in soft tissues and the bones. Lead poisoning has been documented from ancient Rome, ancient Greece, and ancient China.

Characteristics

Lead is a bright and silvery metal with a very slight shade of blue in a dry atmosphere. Upon contact with air, it begins to tarnish by forming a complex mixture of compounds depending on the conditions. The color of the compounds can vary. The tarnish layer can contain significant amounts of carbonates and hydroxycarbonates. It has a few characteristic properties: high density, softness, ductility and malleability, poor electrical conductivity compared to other metals, high resistance to corrosion, and ability to react with organic chemicals.

Various traces of other metals change its properties significantly: the addition of small amounts of antimony or copper increases hardness and improves the corrosion reflection from sulfuric acid for lead. A few other metals also improve only hardness and fight metal fatigue, such as cadmium, tin, or tellurium; metals like sodium or calcium also have this ability, but they weaken the chemical stability. Finally, zinc and bismuth simply impair the corrosion resistance (0.1% bismuth content is the industrial usage threshold). In return, lead impurities mostly worsen the quality of industrial materials, although there are exceptions: for example, small amounts of lead improve the ductility of steel.

Lead has only one common allotrope, which is face-centered cubic, with the lead–lead distance being 349 pm. At 327.5 °C (621.5 °F), lead melts; the melting point is above that of tin (232 °C, 449.5 °F), but significantly below that of germanium (938 °C, 1721 °F).^[6] The boiling point of lead is 1749 °C (3180 °F), which is below those of both tin (2602 °C, 4716 °F) and germanium (2833 °C, 5131 °F). Densities increase down the group: the Ge and Sn values (5.23 and 7.29 g•cm⁻³, respectively) are significantly below that of lead: 11.32 g•cm⁻³.

A lead atom has 82 electrons, having an electronic configuration of [Xe]4f¹⁴5d¹⁰6s²6p². In its compounds, lead (unlike the other group 14 elements) most commonly loses its two and not four outermost electrons, becoming lead(II) ions, Pb²⁺. Such unusual behavior is rationalized by considering the inert pair effect, which occurs because of the stabilization of the 6s-orbital due to relativistic effects, which are stronger closer to the bottom of the periodic table. Tin shows a weaker such effect: tin(II) is still a reducer.

The figures for electrode potential show that lead is only slightly easier to oxidize than hydrogen. Lead thus can dissolve in acids, but this is often impossible due to specific problems (such as the formation of insoluble salts). Powdered lead burns with a bluish-white flame. As with many metals, finely divided powdered lead exhibits pyrophoricity. Toxic fumes are released when lead is burned.

Isotopes

Lead occurs naturally on Earth exclusively in the form of four isotopes: lead-204, -206, -207, and -208. All four can be radioactive as the hypothetical alpha decay of any would be exothermic, but the lower half-life limit has been put only for lead-204: over 1.4×10^{17} years. This effect is, however, so weak that natural lead poses no radiation hazard. Three isotopes are also found in three of the four major decay chains: lead-206, -207 and -208 are final decay products of uranium-238, uranium-235, and thorium-232, respectively.

Since the amounts of them in nature depend also on other elements' presence, the isotopic composition of natural lead varies by sample: in particular, the relative amount of lead-206 varies between 20.84% and 27.78%.

Aside from the stable ones, thirty-four radioisotopes have been synthesized: they have mass numbers of 178–215. Lead-205 is the most stable radioisotope of lead, with a half-life of over 10^7 years. 47 nuclear isomers (long-lived excited nuclear states), corresponding to 24 lead isotopes, have been characterized. The most long-lived isomer is lead-204m2 (half-life of about 1.1 hours).

Chemical Reactivity

Lead is classified as a post-transition metal and is also a member of the carbon group. Lead only forms a protective oxide layer although finely powdered highly purified lead can ignite in air. Melted lead is oxidized in air to lead monoxide. All chalcogens oxidize lead upon heating.

Fluorine does not oxidize cold lead. Hot lead can be oxidized, but the formation of a protective halide layer lowers the intensity of the reaction above 100 °C (210 °F). The reaction with chlorine is similar: thanks to the chloride layer, lead persistence against chlorine surpasses those of copper or steel up to 300 °C (570 °F).

Water in the presence of oxygen attacks lead to start an accelerating reaction. The presence of carbonates or sulfates results in the formation of insoluble lead salts, which protect the metal from corrosion. So does carbon dioxide, as the insoluble lead carbonate is formed; however, an excess of the gas leads to the formation of the soluble bicarbonate; this makes the use of lead pipes dangerous. Lead dissolves in organic acids (in the presence of oxygen) and concentrated ($\geq 80\%$) sulfuric acid thanks to complexation; however, it is only weakly affected by hydrochloric acid and is stable against hydrofluoric acid, as the corresponding halides are weakly soluble. Lead also dissolves in quite concentrated alkalis ($\geq 10\%$) because of the amphoteric character and solubility of plumbites.

Compounds

Lead compounds exist mainly in two main oxidation states, +2 and +4. The former is more common. Inorganic lead(IV) compounds are typically strong oxidants or exist only in highly acidic solutions.

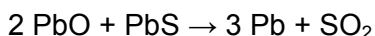
Oxides and Sulfides

Three oxides are known: lead(II) oxide or lead monoxide (PbO), lead tetroxide (Pb_3O_4) (sometimes called "minimum"), and lead dioxide (PbO_2). The monoxide exists as two allotropes: α - PbO and β - PbO , both with layer structure and tetracoordinated lead. The alpha polymorph is red-colored and has the Pb–O distance of 230 pm; the beta polymorph is yellow-colored and has the Pb–O distance of 221 and 249 pm (due to asymmetry). Both polymorphs can exist under standard conditions (beta with small (10^{-5} relative) impurities, such as Si, Ge, Mo, etc.). PbO reacts with acids to form salts, and with alkalis to give plumbites, $[\text{Pb}(\text{OH})_3]^-$ or $[\text{Pb}(\text{OH})_4]^{2-}$. The monoxide oxidizes in air to trilead tetroxide, which at 550 °C (1020 °F) degrades back into PbO .

The dioxide may be prepared by, for example, halogenization of lead(II) salts. Regardless the polymorph, it has a black-brown color. The alpha allotrope is rhombohedral, and the beta allotrope is tetragonal. Both allotropes are black-brown in color and always contain some water, which cannot be removed, as heating also causes decomposition (to PbO and Pb_3O_4).

The dioxide is a powerful oxidizer: it can oxidize hydrochloric and sulfuric acids. It does not react with alkaline solution, but reacts with solid alkalis to give hydroxyplumbates, or with basic oxides to give plumbates.

Reaction of lead salts with hydrogen sulfide yields lead monosulfide. The solid has the rocksalt-like simple cubic structure, which it keeps up to the melting point, 1114 °C (2037 °F). When heated in air, it oxidizes to the sulfate and then the monoxide. Lead monosulfide is almost insoluble in water, weak acids, and $(\text{NH}_4)_2\text{S}/(\text{NH}_4)_2\text{S}_2$ solution is the key for separation of lead from analytical groups I to III ions, tin, arsenic, and antimony. However, it dissolves in nitric and hydrochloric acids, to give elemental sulfur and hydrogen sulfide, respectively. Upon heating under high pressures with sulfur, it gives the disulfide. In the compound, the lead atoms are linked octahedrally with the sulfur atoms. It is also a semiconductor. A mixture of the monoxide and the monosulfide when heated forms the metal.



Halides and Other Salts

Heating lead carbonate with hydrogen fluoride yields the hydrofluoride, which decomposes to the difluoride when it melts. This white crystalline powder is more soluble than the diiodide, but less than the dibromide and the dichloride. The tetrafluoride, a yellow crystalline powder, is unstable.

Other dihalides are obtained upon heating lead(II) salts with the halides of other metals; lead dihalides precipitate to give white orthorhombic crystals (diiodide forms yellow hexagonal crystals). They can also be obtained by direct reaction of their constituent elements at temperature exceeding melting points of dihalides. Their solubility increases with temperature; adding more halides first decreases the solubility, but then increases due to complexation, with the maximum coordination number being 6.

The complexation depends on halide ion numbers, atomic number of the alkali metal, the halide of which is added, temperature and solution ionic strength. The tetrachloride is obtained upon dissolving the dioxide in hydrochloric acid; to prevent the exothermic decomposition, it is kept under concentrated sulfuric acid. The tetrabromide may not, and the tetraiodide definitely does not exist. The diastatide has also been prepared.

The metal is not attacked by sulfuric or hydrochloric acids. It dissolves in nitric acid with the evolution of nitric oxide gas to form dissolved $\text{Pb}(\text{NO}_3)_2$. It is a well-soluble solid in water; it is thus a key to receive the precipitates of halides, sulfate, chromate, carbonate, and basic carbonate $\text{Pb}_3(\text{OH})_2(\text{CO}_3)_2$ salts of lead.

Organolead

The best-known compounds are the two simplest plumbane derivatives: tetramethyllead (TML) and tetraethyllead (TEL). The homologs of these, as well as hexaethyldilead (HEDL), are of lesser stability. The tetraalkyl derivatives contain lead(IV), where the Pb–C bonds are covalent. They thus resemble typical organic compounds.

Lead readily forms an equimolar alloy with sodium metal that reacts with alkyl halides to form organometallic compounds of lead such as tetraethyllead. The Pb–C bond energies in TML and TEL are only 167 and 145 kJ/mol; the compounds thus decompose upon heating, with first signs of TEL composition seen at 100 °C (210 °F).

The pyrolysis yields of elemental lead and alkyl radicals; their interreaction causes the synthesis of HEDL. TML and TEL also decompose upon sunlight or UV light. In presence of chlorine, the alkyls begin to be replaced with chlorides; the R_2PbCl_2 in the presence of HCl (a by-product of the previous reaction) leads to the complete mineralization to give $PbCl_2$. Reaction with bromine follows the same principle.

Applications

Elemental Form

Contrary to popular belief, pencil leads in wooden pencils have never been made from lead. The term comes from the Roman stylus, called the *penicillus*, a small brush used for painting. When the pencil originated as a wrapped graphite writing tool, the particular type of graphite being used was named *plumbago* (lit. *act for lead*, or *lead mockup*).

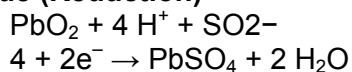
Lead is used in applications where its low melting point, ductility and high density are advantageous. The low melting point makes casting of lead easy, and therefore small arms ammunition and shotgun pellets can be cast with minimal technical equipment. It is also inexpensive and denser than other common metals.

Because of its high density and resistance from corrosion, lead is used for the ballast keel of sailboats. Its high density allows it to counterbalance the heeling effect of wind on the sails while at the same time occupying a small volume and thus offering the least underwater resistance.

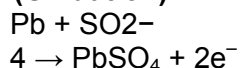
For the same reason it is used in scuba diving weight belts to counteract the diver's natural buoyancy and that of his equipment. It does not have the weight-to-volume ratio of many heavy metals, but its low cost increases its use in these and other applications.

More than half of the US lead production (at least 1.15 million tons in 2000) is used for automobiles, mostly as electrodes in the lead–acid battery, used extensively as a car battery.

Cathode (Reduction)



Anode (Oxidation)



Lead is used as electrodes in the process of electrolysis. It is used in solder for electronics, although this usage is being phased out by some countries to reduce the amount of environmentally hazardous waste, and in high voltage power cables as sheathing material to prevent water diffusion into insulation. Lead is one of three metals used in the Oddy test for museum materials, helping detect organic acids, aldehydes, and acidic gases. It is also used as shielding from radiation (e.g., in X-ray rooms). Molten lead is used as a coolant (e.g., for lead cooled fast reactors).

Lead is added to brass to reduce machine tool wear. In the form of strips, or tape, lead is used for the customization of tennis rackets. Tennis rackets of the past sometimes had lead added to them by the manufacturer to increase weight. It is also used to form glazing bars for stained glass or other multi-lit windows. The practice has become less common, not for danger but for stylistic reasons.

Lead, or *sheet-lead*, is used as a sound deadening layer in some areas in wall, floor and ceiling design in sound studios where levels of airborne and mechanically produced sound are targeted

for reduction or virtual elimination. It is the traditional base metal of organ pipes, mixed with varying amounts of tin to control the tone of the pipe.

Compounds

Lead compounds are used as a coloring element in ceramic glazes, notably in the colors red and yellow. Lead is frequently used in polyvinyl chloride (PVC) plastic, which coats electrical cords.

Lead is used in some candles to treat the wick to ensure a longer, more even burn. Because of the dangers, European and North American manufacturers use more expensive alternatives such as zinc. Lead glass is composed of 12–28% lead oxide. It changes the optical characteristics of the glass and reduces the transmission of radiation.

Some artists using oil-based paints continue to use lead carbonate white, citing its properties in comparison with the alternatives. Tetra-ethyl lead is used as an anti-knock additive for aviation fuel in piston-driven aircraft. Lead-based semiconductors, such as lead telluride, lead selenide and lead antimonide are finding applications in photovoltaic (solar energy) cells and infrared detectors.

Former Applications

Lead pigments were used in lead paint for white as well as yellow, orange, and red. Most uses have been discontinued due to the dangers of lead poisoning. Beginning April 22, 2010, US federal law requires that contractors performing renovation, repair, and painting projects that disturb more than six square feet of paint in homes, child care facilities, and schools built before 1978 must be certified and trained to follow specific work practices to prevent lead contamination.

Lead chromate is still in industrial use. Lead carbonate (white) is the traditional pigment for the priming medium for oil painting, but it has been largely displaced by the zinc and titanium oxide pigments. It was also quickly replaced in water-based painting mediums. Lead carbonate white was used by the Japanese geisha and in the West for face-whitening make-up, which was detrimental to health.

Lead is the hot metal that was used in hot metal typesetting. It was used for plumbing (hence the name) as well as a preservative for food and drink in Ancient Rome. Until the early 1970s, lead was used for joining cast iron water pipes and used as a material for small diameter water pipes.

Tetraethyllead was used in leaded fuels to reduce engine knocking, but this practice has been phased out across many countries of the world in efforts to reduce toxic pollution that affected humans and the environment.

Lead was used to make bullets for slings. Lead was used for shotgun pellets in the US until about 1992 when it was outlawed (for waterfowl hunting only) and replaced by non-toxic shot, primarily steel pellets. In the Netherlands, the use of lead shot for hunting and sport shooting was banned in 1993, which caused a large drop in lead emission, from 230 tons in 1990 to 47.5 tons in 1995, two years after the ban.

Lead was a component of the paint used on children's toys – now restricted in the United States and across Europe (ROHS Directive). Lead was used in car body filler, which was used in many custom cars in the 1940s–60s. Hence the term Leadsled. Lead is a superconductor with a transition temperature of 7.2 K, and therefore IBM tried to make a Josephson effect computer out of a lead alloy.

Lead was also used in pesticides before the 1950s, when fruit orchards were treated especially against the codling moth. A lead cylinder attached to a long line was used by sailors for the vital navigational task of determining water depth by *heaving the lead* at regular intervals. A soft tallow insert at its base allowed the nature of the sea bed to be determined, further aiding position finding.

Health Effects

Lead is a highly poisonous metal (regardless if inhaled or swallowed), affecting almost every organ and system in the body. The main target for lead toxicity is the nervous system, both in adults and children. Long-term exposure of adults can result in decreased performance in some tests that measure functions of the nervous system. Long-term exposure to lead or its salts (especially soluble salts or the strong oxidant PbO_2) can cause nephropathy, and colic-like abdominal pains. It may also cause weakness in fingers, wrists, or ankles. Lead exposure also causes small increases in blood pressure, particularly in middle-aged and older people and can cause anemia. Exposure to high lead levels can severely damage the brain and kidneys in adults or children and ultimately cause death. In pregnant women, high levels of exposure to lead may cause miscarriage.

Chronic, high-level exposure have shown to reduce fertility in males. Lead also damages nervous connections (especially in young children) and cause blood and brain disorders. Lead poisoning typically results from ingestion of food or water contaminated with lead; but may also occur after accidental ingestion of contaminated soil, dust, or lead-based paint. It is rapidly absorbed into the bloodstream and is believed to have adverse effects on the central nervous system, the cardiovascular system, kidneys, and the immune system. The component limit of lead ($1.0 \mu\text{g/g}$) is a test benchmark for pharmaceuticals, representing the maximum daily intake an individual should have. However, even at this low level, a prolonged intake can be hazardous to human beings. The treatment for lead poisoning consists of dimercaprol and succimer.

The concern about lead's role in cognitive deficits in children has brought about widespread reduction in its use (lead exposure has been linked to learning disabilities). Most cases of adult elevated blood lead levels are workplace-related. High blood levels are associated with delayed puberty in girls. Lead has been shown many times to permanently reduce the cognitive capacity of children at extremely low levels of exposure.

During the 20th century, the use of lead in paint pigments was sharply reduced because of the danger of lead poisoning, especially to children. By the mid-1980s, a significant shift in lead end-use patterns had taken place. Much of this shift was a result of the U.S. lead consumers' compliance with environmental regulations that significantly reduced or eliminated the use of lead in non-battery products, including gasoline, paints, solders, and water systems. Lead use is being further curtailed by the European Union's RoHS directive. Lead may still be found in harmful quantities in stoneware, vinyl (such as that used for tubing and the insulation of electrical cords), and Chinese brass. Older houses may still contain substantial amounts of lead paint. White lead paint has been withdrawn from sale in industrialized countries, but the yellow lead chromate is still in use. Old paint should not be stripped by sanding, as this produces inhalable dust.

Lead salts used in pottery glazes have on occasion caused poisoning, when acidic drinks, such as fruit juices, have leached lead ions out of the glaze. It has been suggested that what was known as "Devon colic" arose from the use of lead-lined presses to extract apple juice in the manufacture of cider. Lead is considered to be particularly harmful for women's ability to reproduce. Lead(II) acetate (also known as *sugar of lead*) was used in the Roman Empire as a sweetener for wine, and some consider this to be the cause of the dementia that affected many of the Roman Emperors and even be a partial reason for the Roman Empire's fall.

Biochemistry of Poisoning

In the human body, lead inhibits porphobilinogen synthase and ferrochelatase, preventing both porphobilinogen formation and the incorporation of iron into protoporphyrin IX, the final step in heme synthesis. This causes ineffective heme synthesis and subsequent microcytic anemia. At lower levels, it acts as a calcium analog, interfering with ion channels during nerve conduction. This is one of the mechanisms by which it interferes with cognition. Acute lead poisoning is treated using disodium calcium edetate: the calcium chelate of the disodium salt of ethylenediamine-tetracetic acid (EDTA). This chelating agent has a greater affinity for lead than for calcium and so the lead chelate is formed by exchange. This is then excreted in the urine leaving behind harmless calcium. According to the Agency for Toxic Substance and Disease Registry, a small amount of ingested lead (1%) will store itself in bones, and the rest will be excreted by an adult through urine and feces within a few weeks of exposure. However, only about 32% of lead will be excreted by a child.

Exposure

Exposure to lead and lead chemicals can occur through inhalation, ingestion and dermal contact. Most exposure occurs through ingestion or inhalation; in the U.S. the skin exposure is unlikely as leaded gasoline additives are no longer used. Lead exposure is a global issue as lead mining and lead smelting are common in many countries. Most countries have stopped using lead-containing gasoline by 2007. Lead exposure mostly occurs through ingestion. Lead paint is the major source of lead exposure for children. As lead paint deteriorates, it peels, is pulverized into dust and then enters the body through hand-to-mouth contact or through contaminated food, water or alcohol. Ingesting certain home remedy medicines may also expose people to lead or lead compounds. Lead can be ingested through fruits and vegetables contaminated by high levels of lead in the soils they were grown in.

Soil is contaminated through particulate accumulation from lead in pipes, lead paint and residual emissions from leaded gasoline that was used before the Environment Protection Agency issued the regulation around 1980. The use of lead for water pipes is problematic in areas with soft or (and) acidic water. Hard water forms insoluble layers in the pipes while soft and acidic water dissolves the lead pipes.

Inhalation is the second major pathway of exposure, especially for workers in lead-related occupations. Almost all inhaled lead is absorbed into the body, the rate is 20–70% for ingested lead; children absorb more than adults. Dermal exposure may be significant for a narrow category of people working with organic lead compounds, but is of little concern for general population. The rate of skin absorption is also low for inorganic lead.

Mercury - Inorganic Contaminant 0.002 mg/L MCL

EPA regulates mercury in drinking water to protect public health. Mercury may cause health problems if present in public or private water supplies in amounts greater than the drinking water standard set by EPA.

What is Mercury?

Mercury is a liquid metal found in natural deposits such as ores containing other elements.

Uses for Mercury.

Electrical products such as dry-cell batteries, fluorescent light bulbs, switches, and other control equipment account for 50 percent of mercury used.

What are Mercury's Health Effects?

Some people who drink water containing mercury well in excess of the maximum contaminant level (MCL) for many years could experience kidney damage.

This health effects language is not intended to catalog all possible health effects for mercury. Rather, it is intended to inform consumers of some of the possible health effects associated with mercury in drinking water when the rule was finalized.



What are EPA's Drinking Water Regulations for Mercury?

In 1974, Congress passed the Safe Drinking Water Act. This law requires EPA to determine the level of contaminants in drinking water at which no adverse health effects are likely to occur. These non-enforceable health goals, based solely on possible health risks and exposure over a lifetime with an adequate margin of safety, are called maximum contaminant level goals (MCLG). Contaminants are any physical, chemical, biological or radiological substances or matter in water.

The MCLG for mercury is 0.002 mg/L or 2 ppb. EPA has set this level of protection based on the best available science to prevent potential health problems. EPA has set an enforceable regulation for mercury, called a maximum contaminant level (MCL), at 0.002 mg/L or 2 ppb. MCLs are set as close to the health goals as possible, considering cost, benefits and the ability of public water systems to detect and remove contaminants using suitable treatment technologies. In this case, the MCL equals the MCLG, because analytical methods or treatment technology do not pose any limitation.

The Phase II Rule, the regulation for mercury, became effective in 1992. The Safe Drinking Water Act requires EPA to periodically review the national primary drinking water regulation for each contaminant and revise the regulation, if appropriate. EPA reviewed mercury as part of the Six Year Review and determined that the 0.002 mg/L or 2 ppb MCLG and 0.002 mg/L or 2 ppb MCL for mercury are still protective of human health.

States may set more stringent drinking water MCLGs and MCLs for mercury than EPA.

How does Mercury get into my Drinking Water?

The major sources of mercury in drinking water are erosion of natural deposits; discharge from refineries and factories; runoff from landfills; and runoff from croplands.

A federal law called the Emergency Planning and Community Right to Know Act (EPCRA) requires facilities in certain industries, which manufacture, process, or use significant amounts of toxic chemicals, to report annually on their releases of these chemicals. For more information on the uses and releases of chemicals in your state, contact the Community Right-to-Know Hotline: (800) 424-9346.

How will I know if Mercury is in my Drinking Water?

When routine monitoring indicates that mercury levels are above the MCL, your water supplier must take steps to reduce the amount of mercury so that it is below that level. Water suppliers must notify their customers as soon as practical, but no later than 30 days after the system learns of the violation. Additional actions, such as providing alternative drinking water supplies, may be required to prevent serious risks to public health.

If your water comes from a household well, check with your health department or local water systems that use ground water for information on contaminants of concern in your area.

How will Mercury be removed from my Drinking Water?

The following treatment method(s) have proven to be effective for removing mercury to below 0.002 mg/L or 2 ppb: coagulation/filtration, granular activated carbon, lime softening, and reverse osmosis.

How do I learn more about my Drinking Water?

EPA strongly encourages people to learn more about their drinking water, and to support local efforts to protect the supply of safe drinking water and upgrade the community water system. Your water bill or telephone book's government listings are a good starting point for local information.

Contact your water utility. EPA requires all community water systems to prepare and deliver an annual consumer confidence report (CCR) (sometimes called a water quality report) for their customers by July 1 of each year. If your water provider is not a community water system, or if you have a private water supply, request a copy from a nearby community water system.

Mercury Explained

Mercury is a chemical element with the symbol **Hg** and atomic number 80. It is also known as **quicksilver** or **hydrargyrum** (< Greek "hydr-" *water* and "argyros" *silver*). A heavy, silvery d-block element, mercury is the only metal that is liquid at standard conditions for temperature and pressure; the only other element that is liquid under these conditions is bromine, though metals such as caesium, gallium, and rubidium melt just above room temperature. With a freezing point of $-38.83\text{ }^{\circ}\text{C}$ and boiling point of $356.73\text{ }^{\circ}\text{C}$, mercury has one of the narrowest ranges of its liquid state of any metal.

Mercury occurs in deposits throughout the world mostly as cinnabar (mercuric sulfide). The red pigment vermilion is mostly obtained by reduction from cinnabar. Cinnabar is highly toxic by ingestion or inhalation of the dust. Mercury poisoning can also result from exposure to water-soluble forms of mercury (such as mercuric chloride or methylmercury), inhalation of mercury vapor, or eating seafood contaminated with mercury.

Mercury is used in thermometers, barometers, manometers, sphygmomanometers, float valves, mercury switches, and other devices though concerns about the element's toxicity have led to mercury thermometers and sphygmomanometers being largely phased out in clinical environments in favor of alcohol-filled, galinstan-filled, digital, or thermistor-based instruments. It

remains in use in scientific research applications and in amalgam material for dental restoration. It is used in lighting: electricity passed through mercury vapor in a phosphor tube produces short-wave ultraviolet light which then causes the phosphor to fluoresce, making visible light.

Physical Properties

Mercury is a heavy, silvery-white metal. As compared to other metals, it is a poor conductor of heat, but a fair conductor of electricity. Mercury has an exceptionally low melting temperature for a d-block metal. A complete explanation of this delves deep into the realm of quantum physics, but it can be summarized as follows: mercury has a unique electronic configuration where electrons fill up all the available 1s, 2s, 2p, 3s, 3p, 3d, 4s, 4p, 4d, 4f, 5s, 5p, 5d and 6s subshells. As such configuration strongly resists removal of an electron, mercury behaves similarly to noble gas elements, which form weak bonds and thus easily melting solids. The stability of the 6s shell is due to the presence of a filled 4f shell. An f shell poorly screens the nuclear charge that increases the attractive Coulomb interaction of the 6s shell and the nucleus (see lanthanide contraction).

The absence of a filled inner *f* shell is the reason for the somewhat higher melting temperature of cadmium and zinc, although both these metals still melt easily and, in addition, have unusually low boiling points. On the other hand, gold, which is one space to the left of mercury on the periodic table, has atoms with one less 6s electron than mercury. Those electrons are more easily removed and are shared between the gold atoms forming relatively strong metallic bonds.

Chemical Properties

Mercury does not react with most acids, such as dilute sulfuric acid, although oxidizing acids such as concentrated sulfuric acid and nitric acid or aqua regia dissolve it to give sulfate, nitrate, and chloride salts. Like silver, mercury reacts with atmospheric hydrogen sulfide. Mercury even reacts with solid sulfur flakes, which are used in mercury spill kits to absorb mercury vapors (spill kits also use activated carbon and powdered zinc).

Amalgams

Mercury dissolves to form amalgams with gold, zinc and many other metals. Because iron is an exception, iron flasks have been traditionally used to trade mercury. Other metals that do not form amalgams with mercury include tantalum, tungsten and platinum. Sodium amalgam is a common reducing agent in organic synthesis, and is also used in high-pressure sodium lamps.

Mercury readily combines with aluminum to form a mercury-aluminum amalgam when the two pure metals come into contact. Since the amalgam destroys the aluminum oxide layer which protects metallic aluminum from oxidizing in-depth (as in iron rusting), even small amounts of mercury can seriously corrode aluminum. For this reason, mercury is not allowed aboard an aircraft under most circumstances because of the risk of it forming an amalgam with exposed aluminum parts in the aircraft.

Isotopes

There are seven stable isotopes of mercury with ^{202}Hg being the most abundant (29.86%). The longest-lived radioisotopes are ^{194}Hg with a half-life of 444 years, and ^{203}Hg with a half-life of 46.612 days. Most of the remaining radioisotopes have half-lives that are less than a day. ^{199}Hg and ^{201}Hg are the most often studied NMR-active nuclei, having spins of $\frac{1}{2}$ and $\frac{3}{2}$ respectively.

History



The symbol for the planet Mercury (☿) has been used since ancient times to represent the element.

In China and Tibet, mercury use was thought to prolong life, heal fractures, and maintain generally good health, although it is now known that exposure to mercury leads to serious adverse health effects. The first emperor of China, Qín Shǐ Huáng Dì — allegedly buried in a tomb that contained rivers of flowing mercury on a model of the land he ruled, representative of the rivers of China — was killed by drinking a mercury and powdered jade mixture formulated by Qin alchemists (causing liver failure, mercury poisoning, and brain death) who intended to give him eternal life.

The ancient Greeks used mercury in ointments; the ancient Egyptians and the Romans used it in cosmetics which sometimes deformed the face. In Lamanai, once a major city of the Maya civilization, a pool of mercury was found under a marker in a Mesoamerican ballcourt. By 500 BC mercury was used to make amalgams (Medieval Latin *amalgama*, "alloy of mercury") with other metals.

Alchemists thought of mercury as the First Matter from which all metals were formed. They believed that different metals could be produced by varying the quality and quantity of sulfur contained within the mercury. The purest of these was gold, and mercury was called for in attempts at the transmutation of base (or impure) metals into gold, which was the goal of many alchemists.

Hg is the modern chemical symbol for mercury. It comes from *hydrargyrum*, a Latinized form of the Greek word ὕδραργυρος (*hydrargyros*), which is a compound word meaning "water-silver" (hydr- = water, argyros = silver) — since it is liquid like water and shiny like silver. The element was named after the Roman god Mercury, known for speed and mobility. It is associated with the planet Mercury; the astrological symbol for the planet is also one of the alchemical symbols for the metal; the Sanskrit word for alchemy is *Rasavātam* which means "the way of mercury". Mercury is the only metal for which the alchemical planetary name became the common name. The mines in Almadén (Spain), Monte Amiata (Italy), and Idrija (now Slovenia) dominated mercury production from the opening of the mine in Almadén 2500 years ago, until new deposits were found at the end of the 19th century.

Chemistry

Mercury exists in two main oxidation states, I and II. Higher oxidation states are unimportant, but have been detected, e.g., mercury(IV) fluoride (HgF₄) but only under extraordinary conditions.

Compounds of Mercury (I)

Different from its lighter neighbors, cadmium and zinc, mercury forms simple stable compounds with metal-metal bonds. The mercury(I) compounds are diamagnetic and feature the dimeric cation, Hg₂²⁺.

Stable derivatives include the chloride and nitrate. Treatment of Hg(I) compounds complexation with strong ligands such as sulfide, cyanide, etc. induces disproportionation to Hg^{2+} and elemental mercury. Mercury(I) chloride, a colorless solid also known as calomel, is really the compound with the formula Hg_2Cl_2 , with the connectivity Cl-Hg-Hg-Cl . It is a standard in electrochemistry. It reacts with chlorine to give mercuric chloride, which resists further oxidation. Indicative of its tendency to bond to itself, mercury forms mercury polycations, which consist of linear chains of mercury centers, capped with a positive charge. One example is $\text{Hg}_2^{+3}(\text{AsF}_6)_2$.

Compounds of Mercury (II)

Mercury(II) is the most common oxidation state and is the main one in nature as well. All four mercuric halides are known. The form tetrahedral complexes with other ligands but the halides adopt linear coordination geometry, somewhat like Ag^+ does. Best known is mercury(II) chloride, an easily sublimating white solid. HgCl_2 forms coordination complexes that are typically tetrahedral, e.g. $\text{HgCl}_2\cdot 4$.

Mercury(II) oxide, the main oxide of mercury, arises when the metal is exposed to air for long periods at elevated temperatures. It reverts to the elements upon heating near 400°C , as was demonstrated by Priestly in an early synthesis of pure oxygen. Hydroxides of mercury are poorly characterized, as they are for its neighbors gold and silver.

Being a soft metal, mercury forms very stable derivatives with the heavier chalcogens. Preeminent is mercury(II) sulfide, HgS , which occurs in nature as the ore cinnabar and is the brilliant pigment vermilion. Like ZnS , HgS crystallizes in two forms, the reddish cubic form and the black zinc blende form. Mercury(II) selenide (HgSe) and mercury(II) telluride (HgTe) are also known, these as well as various derivatives, e.g. mercury cadmium telluride and mercury zinc telluride being semiconductors useful as infrared detector materials.

Mercury(II) salts form a variety of complex derivatives with ammonia. These include Millon's base (Hg_2N^+), the one-dimensional polymer (salts of HgNH_2) $_n$, and "fusible white precipitate" or $[\text{Hg}(\text{NH}_3)_2]\text{Cl}_2$. Known as Nessler's reagent, potassium tetraiodomercurate(II) ($\text{HgI}_2\cdot 4$) is still occasionally used to test for ammonia owing to its tendency to form the deeply colored iodide salt of Millon's base.

Higher Oxidation States

Oxidation states above +2 in a non-charged species are extremely rare, although a cyclic mercurinium(IV) cation, with three substituents, is an intermediate in oxymercuration reactions. In 2007, a report of synthesis of a mercury(IV) compound, mercury(IV) fluoride, was published. In the 1970s, there was a claim on synthesis of a mercury(III) compound, but it is now thought to be false.

Organomercury Compounds

Organic mercury compounds are historically important but are of little industrial value in the western world. Mercury(II) salts are a rare examples of simple metal complexes that react directly with aromatic rings. Organomercury compounds are always divalent and usually two-coordinate and linear geometry. Unlike organocadmium and organozinc compounds, organomercury, . compounds do not react with water. They usually have the formula HgR_2 , which are often volatile, or HgRX , which are often solids, where R is aryl or alkyl and X is usually halide or acetate. Methylmercury, a generic term for compounds with the formula CH_3HgX , is a dangerous family of compounds that are often found in polluted water. They arise by a process known as biomethylation.

Applications

Mercury is used primarily for the manufacture of industrial chemicals or for electrical and electronic applications. It is used in some thermometers, especially ones which are used to measure high temperatures. A still increasing amount is used as gaseous mercury in fluorescent lamps, while most of the other applications are slowly phased out due to health and safety regulations and is in some applications replaced with less toxic but considerably more expensive Galinstan alloy.

Medicine

Mercury and its compounds have been used in medicine, although they are much less common today than they once were, now that the toxic effects of mercury and its compounds are more widely understood. The element mercury is an ingredient in dental amalgams. Thiomersal (called *Thimerosal* in the United States) is an organic compound used as a preservative in vaccines, though this use is in decline. Another mercury compound Merbromin (Mercurochrome) is a topical antiseptic used for minor cuts and scrapes is still in use in some countries.

Since the 1930s some vaccines have contained the preservative thiomersal, which is metabolized or degraded to ethyl mercury. Although it was widely speculated that this mercury-based preservative can cause or trigger autism in children, scientific studies showed no evidence supporting any such link. Nevertheless thiomersal has been removed from or reduced to trace amounts in all U.S. vaccines recommended for children 6 years of age and under, with the exception of inactivated influenza vaccine.

Mercury in the form of one of its common ores, cinnabar, is used in various traditional medicines, especially in traditional Chinese medicine. Review of its safety has found cinnabar can lead to significant mercury intoxication when heated, consumed in overdose or taken long term, and can have adverse effects at therapeutic doses, though this is typically reversible at therapeutic doses. Although this form of mercury appears less toxic than others, its use in traditional Chinese medicine has not yet been justified as the therapeutic basis for the use of cinnabar is not clear.

Today, the use of mercury in medicine has greatly declined in all respects, especially in developed countries. Thermometers and sphygmomanometers containing mercury were invented in the early 18th and late 19th centuries, respectively. In the early 21st century, their use is declining and has been banned in some countries, states and medical institutions. In 2002, the U.S. Senate passed legislation to phase out the sale of non-prescription mercury thermometers. In 2003, Washington and Maine became the first states to ban mercury blood pressure devices. Mercury compounds are found in some over-the-counter drugs, including topical antiseptics, stimulant laxatives, diaper-rash ointment, eye drops, and nasal sprays. The FDA has "inadequate data to establish general recognition of the safety and effectiveness", of the mercury ingredients in these products. Mercury is still used in some diuretics, although substitutes now exist for most therapeutic uses.

Production of Chlorine and Caustic Soda

Chlorine is produced from sodium chloride (common salt, NaCl) using electrolysis to separate the metallic sodium from the chlorine gas. Usually the salt is dissolved in water to produce a brine. By-products of any such chloralkali process are hydrogen (H₂) and sodium hydroxide (NaOH), which is commonly called caustic soda or lye. By far the largest use of mercury in the late 20th century was in the mercury cell process (also called the Castner-Kellner process) where metallic sodium is formed as an amalgam at a cathode made from mercury; this sodium is then reacted with water to produce sodium hydroxide.

Many of the industrial mercury releases of the 20th century came from this process, although modern plants claimed to be safe in this regard. After about 1985, all new chloralkali production facilities that were built in the United States used either membrane cell or diaphragm cell technologies to produce chlorine.

Laboratory Uses

Some medical thermometers, especially those for high temperatures, are filled with mercury; however, they are gradually disappearing. In the United States, non-prescription sale of mercury fever thermometers has been banned since 2003.

Liquid mercury is a part of popular secondary reference electrode (called the calomel electrode) in electrochemistry as an alternative to the standard hydrogen electrode. The calomel electrode is used to work out the electrode potential of half cells. Last, but not least, the triple point of mercury, $-38.8344\text{ }^{\circ}\text{C}$, is a fixed point used as a temperature standard for the International Temperature Scale (ITS-90).

Toxicity and Safety

Mercury and most of its compounds are extremely toxic and must be handled with care; in cases of spills involving mercury (such as from certain thermometers or fluorescent light bulbs), specific cleaning procedures are used to avoid exposure and contain the spill. Protocols call for physically merging smaller droplets on hard surfaces, combining them into a single larger pool for easier removal with an eyedropper, or for gently pushing the spill into a disposable container. Vacuum cleaners and brooms cause greater dispersal of the mercury and should not be used.

Afterwards, fine sulfur, zinc, or some other powder that readily forms an amalgam (alloy) with mercury at ordinary temperatures is sprinkled over the area before itself being collected and properly disposed of. Cleaning porous surfaces and clothing is not effective at removing all traces of mercury and it is therefore advised to discard these kinds of items should they be exposed to a mercury spill.

Mercury can be absorbed through the skin and mucous membranes and mercury vapors can be inhaled, so containers of mercury are securely sealed to avoid spills and evaporation. Heating of mercury, or of compounds of mercury that may decompose when heated, is always carried out with adequate ventilation in order to avoid exposure to mercury vapor. The most toxic forms of mercury are its organic compounds, such as dimethylmercury and methylmercury. Inorganic compounds, such as cinnabar are also highly toxic by ingestion or inhalation. Mercury can cause both chronic and acute poisoning.

Releases in the Environment

Amount of atmospheric mercury deposited at Wyoming's Upper Fremont Glacier over the last 270 years

Preindustrial deposition rates of mercury from the atmosphere may be about 4 ng / (1 L of ice deposit). Although that can be considered a natural level of exposure, regional or global sources have significant effects. Volcanic eruptions can increase the atmospheric source by 4–6 times. Natural sources, such as volcanoes, are responsible for approximately half of atmospheric mercury emissions.

The human-generated half can be divided into the following estimated percentages:

- 65% from stationary combustion, of which coal-fired power plants are the largest aggregate source (40% of U.S. mercury emissions in 1999). This includes power plants fueled with gas where the mercury has not been removed. Emissions from coal combustion are between one and two orders of magnitude higher than emissions from oil combustion, depending on the country.
- 11% from gold production. The three largest point sources for mercury emissions in the U.S. are the three largest gold mines. Hydrogeochemical release of mercury from gold-mine tailings has been accounted as a significant source of atmospheric mercury in eastern Canada.
- 6.8% from non-ferrous metal production, typically smelters.
- 6.4% from cement production.
- 3.0% from waste disposal, including municipal and hazardous waste, crematoria, and sewage sludge incineration.
- 3.0% from caustic soda production.
- 1.4% from pig iron and steel production.
- 1.1% from mercury production, mainly for batteries.
- 2.0% from other sources.

The above percentages are estimates of the global human-caused mercury emissions in 2000, excluding biomass burning, an important source in some regions.

Mercury also enters into the environment through the improper disposal (e.g., land filling, incineration) of certain products. Products containing mercury include: auto parts, batteries, fluorescent bulbs, medical products, thermometers, and thermostats. Due to health concerns (see below), toxics use reduction efforts are cutting back or eliminating mercury in such products. For example, the amount of mercury sold in thermostats in the United States decreased from 14.5 tons in 2004 to 3.9 tons in 2007. Most thermometers now use pigmented alcohol instead of mercury, and galinstan alloy thermometers are also an option. Mercury thermometers are still occasionally used in the medical field because they are more accurate than alcohol thermometers, though both are commonly being replaced by electronic thermometers and less

commonly by galinstan thermometers. Mercury thermometers are still widely used for certain scientific applications because of their greater accuracy and working range.

The United States Clean Air Act, passed in 1990, put mercury on a list of toxic pollutants that need to be controlled to the greatest possible extent. Thus, industries that release high concentrations of mercury into the environment agreed to install maximum achievable control technologies (MACT). In March 2005 EPA rule added power plants to the list of sources that should be controlled and a national cap and trade rule was issued.

States were given until November 2006 to impose stricter controls, and several States are doing so. The rule was being subjected to legal challenges from several States in 2005 and decision was made in 2008. The Clean Air Mercury Rule was struck down by a Federal Appeals Court on February 8, 2008. The rule was deemed not sufficient to protect the health of persons living near coal-fired power plants. The court opinion cited the negative impact on human health from coal-fired power plants' mercury emissions documented in the EPA Study Report to Congress of 1998.

The EPA announced new rules for coal-fired power plants on December 22, 2011. Cement kilns that burn hazardous waste are held to a looser standard than are standard hazardous waste incinerators in the United States, and as a result are a disproportionate source of mercury pollution.

Historically, one of the largest releases was from the Colex plant, a lithium-isotope separation plant at Oak Ridge. The plant operated in the 1950s and 1960s. Records are incomplete and unclear, but government commissions have estimated that some two million pounds of mercury are unaccounted for.

A serious industrial disaster was the dumping of mercury compounds into Minamata Bay, Japan. It is estimated that over 3,000 people suffered various deformities, severe mercury poisoning symptoms or death from what became known as Minamata disease.

Occupational Exposure

Due to the health effects of mercury exposure, industrial and commercial uses are regulated in many countries. The World Health Organization, OSHA, and NIOSH all treat mercury as an occupational hazard, and have established specific occupational exposure limits. Environmental releases and disposal of mercury are regulated in the U.S. primarily by the United States Environmental Protection Agency.

Case control studies have shown effects such as tremors, impaired cognitive skills, and sleep disturbance in workers with chronic exposure to mercury vapor even at low concentrations in the range 0.7–42 $\mu\text{g}/\text{m}^3$. A study has shown that acute exposure (4 – 8 hours) to calculated elemental mercury levels of 1.1 to 44 mg/m^3 resulted in chest pain, dyspnea, cough, hemoptysis, impairment of pulmonary function, and evidence of interstitial pneumonitis. Acute exposure to mercury vapor has been shown to result in profound central nervous system effects, including psychotic reactions characterized by delirium, hallucinations, and suicidal tendency.

Occupational exposure has resulted in broad-ranging functional disturbance, including erethism, irritability, excitability, excessive shyness, and insomnia. With continuing exposure, a fine tremor develops and may escalate to violent muscular spasms. Tremor initially involves the hands and later spreads to the eyelids, lips, and tongue. Long-term, low-level exposure has been associated with more subtle symptoms of erethism, including fatigue, irritability, loss of memory, vivid dreams and depression.

Treatment

Research on the treatment of mercury poisoning is limited. Currently available drugs for acute mercurial poisoning include chelators N-acetyl-D, L-penicillamine (NAP), British Anti-Lewisite (BAL), 2,3-dimercapto-1-propanesulfonic acid (DMPS), and dimercaptosuccinic acid (DMSA). In one small study including 11 construction workers exposed to elemental mercury, patients were treated with DMSA and NAP. Chelation therapy with both drugs resulted in the mobilization of a small fraction of the total estimated body mercury. DMSA was able to increase the excretion of mercury to a greater extent than NAP.

Fish

Fish and shellfish have a natural tendency to concentrate mercury in their bodies, often in the form of methylmercury, a highly toxic organic compound of mercury. Species of fish that are high on the food chain, such as shark, swordfish, king mackerel, bluefin tuna, albacore tuna, and tilefish contain higher concentrations of mercury than others. As mercury and methylmercury are fat soluble, they primarily accumulate in the viscera, although they are also found throughout the muscle tissue. When this fish is consumed by a predator, the mercury level is accumulated. Since fish are less efficient at depurating than accumulating methylmercury, fish-tissue concentrations increase over time. Thus species that are high on the food chain amass body burdens of mercury that can be ten times higher than the species they consume. This process is called biomagnification. Mercury poisoning happened this way in Minamata, Japan, now called Minamata disease.

Regulations

United States

In the United States, the Environmental Protection Agency is charged with regulating and managing mercury contamination. Several laws give the EPA this authority, including the Clean Air Act, the Clean Water Act, the Resource Conservation and Recovery Act, and the Safe Drinking Water Act. Additionally, the Mercury-Containing and Rechargeable Battery Management Act, passed in 1996, phases out the use of mercury in batteries, and provides for the efficient and cost-effective disposal of many types of used batteries. North America contributed approximately 11% of the total global anthropogenic mercury emissions in 1995.

Nitrate (Measured as Nitrogen) - Inorganic Contaminant 10 mg/L MCL

EPA regulates nitrate in drinking water to protect public health. Nitrate may cause health problems if present in public or private water supplies in amounts greater than the drinking water standard set by EPA.

What is Nitrate?

Nitrates and nitrites are nitrogen-oxygen chemical units which combine with various organic and inorganic compounds.

Uses for Nitrate.

The greatest use of nitrates is as a fertilizer. Once taken into the body, nitrates are converted to nitrites.

What are Nitrate's Health Effects?

Infants below six months who drink water containing nitrate in excess of the maximum contaminant level (MCL) could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue baby syndrome.



This health effects language is not intended to catalog all possible health effects for nitrate. Rather, it is intended to inform consumers of some of the possible health effects associated with nitrate in drinking water when the rule was finalized.

What are EPA's Drinking Water Regulations for Nitrate?

In 1974, Congress passed the Safe Drinking Water Act. This law requires EPA to determine the level of contaminants in drinking water at which no adverse health effects are likely to occur. These non-enforceable health goals, based solely on possible health risks and exposure over a lifetime with an adequate margin of safety, are called maximum contaminant level goals (MCLG). Contaminants are any physical, chemical, biological or radiological substances or matter in water.

The MCLG for nitrate is 10 mg/L or 10 ppm. EPA has set this level of protection based on the best available science to prevent potential health problems. EPA has set an enforceable regulation for nitrate, called a maximum contaminant level (MCL), at 10 mg/L or 10 ppm. MCLs are set as close to the health goals as possible, considering cost, benefits and the ability of public water systems to detect and remove contaminants using suitable treatment technologies. In this case, the MCL equals the MCLG, because analytical methods or treatment technology do not pose any limitation.

The Phase II Rule, the regulation for nitrate, became effective in 1992. The Safe Drinking Water Act requires EPA to periodically review the national primary drinking water regulation for each contaminant and revise the regulation, if appropriate. EPA reviewed nitrate as part of the Six Year Review and determined that the 10 mg/L or 10 ppm MCLG and 10 mg/L or 10 ppm MCL for nitrate are still protective of human health.

States may set more stringent drinking water MCLGs and MCLs for nitrate than EPA.

How does Nitrate get into my Drinking Water?

The major sources of nitrates in drinking water are runoff from fertilizer use; leaking from septic tanks, sewage; and erosion of natural deposits.

A federal law called the Emergency Planning and Community Right to Know Act (EPCRA) requires facilities in certain industries, which manufacture, process, or use significant amounts of toxic chemicals, to report annually on their releases of these chemicals. For more information on the uses and releases of chemicals in your state, contact the Community Right-to-Know Hotline: (800) 424-9346.

How will I know if Nitrate is in my Drinking Water?

When routine monitoring indicates that nitrate levels are above the MCL, your water supplier must take steps to reduce the amount of nitrate so that it is below that level. Water suppliers must notify their customers as soon as practical, but no later than 24 hours after the system learns of the violation. Additional actions, such as providing alternative drinking water supplies, may be required to prevent serious risks to public health.

If your water comes from a household well, check with your health department or local water systems that use ground water for information on contaminants of concern in your area.

How will nitrate be Removed from my Drinking Water?

The following treatment method(s) have proven to be effective for removing nitrate to below 10 mg/L or 10 ppm: ion exchange, reverse osmosis, electrodialysis.

How do I learn more about my Drinking Water?

EPA strongly encourages people to learn more about their drinking water, and to support local efforts to protect the supply of safe drinking water and upgrade the community water system. Your water bill or telephone book's government listings are a good starting point for local information.

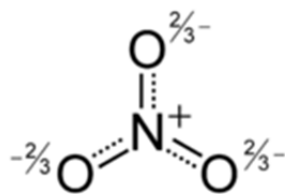
Contact your water utility. EPA requires all community water systems to prepare and deliver an annual consumer confidence report (CCR) (sometimes called a water quality report) for their customers by July 1 of each year. If your water provider is not a community water system, or if you have a private water supply, request a copy from a nearby community water system.

Nitrate Explained

The **nitrate ion** is a polyatomic ion with the molecular formula NO_3^- and a molecular mass of 62.0049 g/mol.

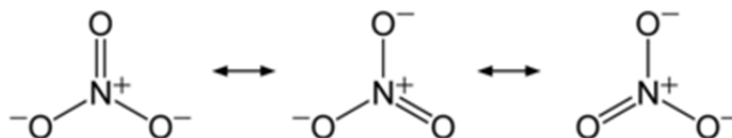
Structure

It is the conjugate base of nitric acid, consisting of one central nitrogen atom surrounded by three identically bonded oxygen atoms in a trigonal planar arrangement. The nitrate ion carries a formal charge of -1. This results from a combination formal charge in which each of the three oxygens carries a $-\frac{2}{3}$ charge, whereas the nitrogen carries a +1 charge, all these adding up to formal charge of the polyatomic nitrate ion.



The nitrate ion. The net charge of the whole ion is 1^- .

This arrangement is commonly used as an example of resonance. Like the isoelectronic carbonate ion, the nitrate ion can be represented by resonance structures:



Properties

Almost all inorganic nitrate salts are soluble in water at standard temperature and pressure. A common example of an inorganic nitrate salt is potassium nitrate (saltpeter).

In organic chemistry a nitrate (not to be confused with Nitro or Nitrite) is a relatively rare functional group with general chemical formula RONO_2 where R stands for any organic residue. They are the esters of nitric acid and alcohols formed by **nitroxylation**. Examples are **methyl nitrate** formed by reaction of methanol and nitric acid, the nitrate of tartaric acid, and the inaccurately named nitroglycerin (which is actually an organic *nitrate* compound, not a *nitro* compound).

Like organic nitro compounds (see below) both organic and inorganic nitrates can be used as propellants and explosives. In these uses, the thermal decomposition of the nitrate yields molecular nitrogen N_2 gas plus considerable chemical energy, due to the high strength of the bond in molecular nitrogen. Especially in inorganic nitrate reactions, oxidation from the nitrate oxygens is also an important energy-releasing process.

Occurrence

Nitrate compounds are found naturally on earth as large deposits, particularly of Chile saltpeter a major source of sodium nitrate.

Nitrites are produced by a number of species of nitrifying bacteria, and the nitrate compounds for gunpowder (see this topic for more) were historically produced, in the absence of mineral nitrate sources, by means of various fermentation processes using urine and dung.

Uses

Nitrates are mainly produced for use as fertilizers in agriculture because of their high solubility and biodegradability. The main nitrates are ammonium, sodium, potassium, and calcium salts. Several million kilograms are produced annually for this purpose.

Other Uses

The second major application of nitrates as oxidizing agents, most notably in explosives where the rapid oxidation of carbon compounds liberates large volumes of gases (see Gunpowder for an example). Sodium nitrate is used to remove air bubbles from molten glass and some ceramics. Mixtures of the molten salt are used to harden some metals.

Detection

Free nitrate ions in solution can be detected by a nitrate ion selective electrode. Such electrodes analogously to the pH selective electrode. This response is partially described by the Nernst equation.

Toxicity/Toxicosis

Nitrate toxicosis can occur through enterohepatic metabolism of nitrate to nitrite being an intermediate. Nitrites oxidize the iron atoms in hemoglobin from ferrous iron (2+) to ferric iron (3+), rendering it unable to carry oxygen. This process can lead to generalized lack of oxygen in organ tissue and a dangerous condition called methemoglobinemia. Although nitrite converts to ammonia, if there is more nitrite than can be converted, the animal slowly suffers from a lack of oxygen.

Human Health Effects

Humans are subject to nitrate toxicity, with infants being especially vulnerable to methemoglobinemia due to nitrate metabolizing triglycerides present at higher concentrations than at other stages of development. Methemoglobinemia in infants is known as blue baby syndrome. Although nitrates in drinking water were once thought to be a contributing factor, there are now significant scientific doubts as to whether there is a causal link. Blue baby syndrome is now thought to be the product of a number of factors, which can include any factor which causes gastric upset, such as diarrheal infection, protein intolerance, heavy metal toxicity etc., with nitrates playing a minor role. Nitrates, if a factor in a specific case, would most often be ingested by infants in high nitrate drinking water. However, nitrate exposure may also occur if eating, for instance, vegetables containing high levels of nitrate. Lettuce may contain elevated nitrate under growth conditions such as reduced sunlight, undersupply of the essential micronutrients molybdenum (Mo) and iron (Fe), or high concentrations of nitrate due to reduced assimilation of nitrate in the plant. High levels of nitrate fertilization also contribute to elevated levels of nitrate in the harvested plant.

Some adults can be more susceptible to the effects of nitrate than others. The methemoglobin reductase enzyme may be under-produced or absent in certain people that have an inherited mutation. Such individuals cannot break down methemoglobin as rapidly as those that do have the enzyme, leading to increased circulating levels of methemoglobin (the implication being that their blood is not as oxygen-rich). Those with insufficient stomach acid (including some vegetarians and vegans) may also be at risk. It is the increased consumption of green, leafy vegetables that typically accompany these types of diets may lead to increased nitrate intake. A wide variety of medical conditions, including food allergies, asthma, hepatitis, and gallstones may be linked with low stomach acid; these individuals may also be highly sensitive to the effects of nitrate.

Methemoglobinemia can be treated with methylene blue, which reduces ferric iron (3+) in affected blood cells back to ferrous iron (2+).

Nitrate also is a by-product of septic systems. To be specific, it is a naturally occurring chemical that is left after the breakdown or decomposition of animal or human waste. Water quality may also be affected through ground water resources that have a high number of septic systems in a watershed. Septics leach down into ground water resources or aquifers and supply nearby bodies of water. Lakes that rely on ground water are often affected by nitrification through this process.

Nitrate in drinking water at levels above the national standard poses an immediate threat to young children. Excessive levels can result in a condition known as "blue baby syndrome". If untreated, the condition can be fatal. Boiling water contaminated with nitrate increases the nitrate concentration and the potential risk.

Nitrite (Measured as Nitrogen) - Inorganic Contaminant 1 mg/L MCL

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Nitrite Explained

The **nitrite** ion, which has the chemical formula NO_2^- , is a symmetric anion with equal N-O bond lengths and a O-N-O bond angle of approximately 120° . Upon protonation, the unstable weak acid nitrous acid is produced. Nitrite can be oxidized or reduced, with the product somewhat dependent on the oxidizing/reducing agent and its strength. The nitrite ion is an ambidentate ligand, and is known to bond to metal centers in at least five different ways. Nitrite is also important in biochemistry as a source of the potent vasodilator nitric oxide. In organic chemistry the NO_2 group is present in nitrous acid esters and nitro compounds. Nitrites are also used in the food production industry for curing meat.

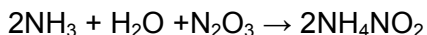
The Nitrite Ion

Nitrite Salts

Sodium nitrite is made industrially by passing "nitrous fumes" into aqueous sodium hydroxide or sodium carbonate solution:



The product is purified by recrystallization. Alkali metal nitrites are thermally stable up to and beyond their melting point (441 °C for KNO₂). Ammonium nitrite can be made from dinitrogen trioxide, N₂O₃, which is formally the anhydride of nitrous acid:



This compound may decompose explosively on heating. In organic chemistry nitrites are used in diazotization reactions.

Structure

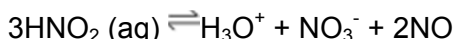
The nitrite ion has a symmetrical structure (C_{2v} symmetry), with both N-O bonds having equal length. In valence bond theory, it is described as a resonance hybrid with equal contributions from two canonical forms that are mirror images of each other. In molecular orbital theory, there is a sigma bond between each oxygen atom and the nitrogen atom, and a delocalized pi bond made from the p orbitals on nitrogen and oxygen atoms which is perpendicular to the plane of the molecule. The negative charge of the ion is equally distributed on the two oxygen atoms. Both nitrogen and oxygen atoms carry a lone pair of electrons. Therefore, the nitrite ion is a Lewis base. Moreover, it can act as an ambidentate ligand towards a metal ion, donating a pair of electrons from either nitrogen or oxygen atoms.

Acid-base Properties

In aqueous solution, nitrous acid is a weak acid:



Nitrous acid is also highly volatile - in the gas phase it exists predominantly as a *trans*-planar molecule. In solution, it is unstable with respect to the disproportionation reaction:



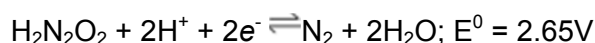
This reaction is slow at 0 °C. Addition of acid to a solution of a nitrite in the presence of a reducing agent, such as iron (II), is a way to make nitric oxide (NO) in the laboratory.

Oxidation and reduction

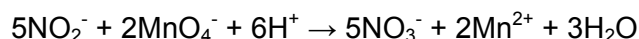
The formal oxidation state of the nitrogen atom in a nitrite is +3. This means that it is can be either oxidized to oxidation states +4 and +5, or reduced to oxidation states as low as -3. Standard reduction potentials for reactions directly involving nitrous acid are shown in the table below:

Half-reaction	E°/V
$\text{NO}_3^- + 3\text{H}^+ + 2\text{e}^- \rightleftharpoons \text{HNO}_2 + \text{H}_2\text{O}$	+0.94
$2\text{HNO}_2 + 4\text{H}^+ + 4\text{e}^- \rightleftharpoons \text{H}_2\text{N}_2\text{O}_2 + 2\text{H}_2\text{O}$	+0.86
$\text{N}_2\text{O}_4 + 2\text{H}^+ + 2\text{e}^- \rightleftharpoons 2\text{HNO}_2$	+1.065
$2\text{HNO}_2 + 4\text{H}^+ + 4\text{e}^- \rightleftharpoons \text{N}_2\text{O} + 3\text{H}_2\text{O}$	+1.29

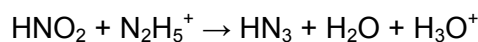
The data can be extended to include products in lower oxidation states. For example:



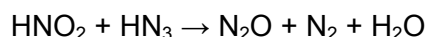
Oxidation reactions usually result in the formation of the nitrate ion, with nitrogen in oxidation state +5. For example, oxidation with permanganate ion can be used for quantitative analysis of nitrite (by titration):



The product of reduction reactions with nitrite ion are varied, depending on the reducing agent used and its strength. With sulfur dioxide, the products are NO and N₂O; with tin (II), Sn²⁺, the product is hyponitrous acid, H₂N₂O₂; reduction all the way to ammonia (NH₃) occurs with hydrogen sulfide. With the hydrazinium cation, N₂H₅⁺, hydrogen azide, HN₃, an explosive compound, is produced:



which can also further react with nitrite:



This reaction is unusual in that it involves compounds with nitrogen in four different oxidation states.

Coordination Complexes

The nitrite ion is known to form coordination complexes in at least five different ways.

1. When donation is from nitrogen to a metal center, the complex is known as a *nitro*-complex.
2. When donation is from one oxygen to a metal center, the complex is known as a *nitrito*-complex.
3. Both oxygen atoms may donate to a metal center, forming a chelate complex.
4. A nitrite ion can form an unsymmetrical bridge between two metal centers, donating through nitrogen to one metal, and through oxygen to the other.
5. A single oxygen atom can bridge to two metal centers.

Alfred Werner studied the nitro-nitrito isomerism (1 and 2) extensively. The red isomer of cobalt pentamine with nitrite is now known to be a nitrito complex, [Co(NH₃)₅(ONO)]²⁺; it is metastable and isomerizes to the yellow nitro complex [Co(NH₃)₅(NO₂)]²⁺. An example of chelating nitrite (3) was found in [Cu(bipy)₂(O₂N)]NO₃ - "bipy" is the bidentate ligand 2,2'-bipyridyl, with the two bipy ligands occupying four coordination sites on the copper ion, so that the nitrite is forced to occupy two sites in order to achieve an octahedral environment around the copper ion.

Nitrite in Biochemistry

Sodium nitrite is used for the curing of meat because it prevents bacterial growth and, in a reaction with the meat's myoglobin, gives the product a desirable dark red color. Because of the

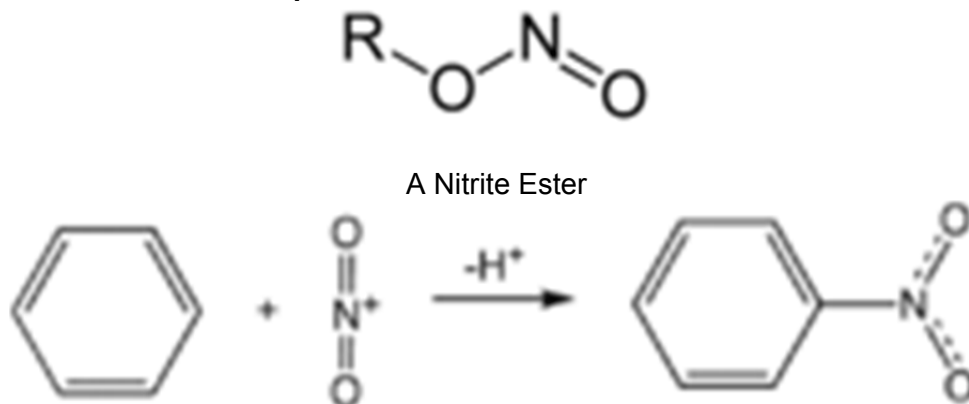
relatively high toxicity of nitrite (the lethal dose in humans is about 22 milligrams per kilogram of body weight), the maximum allowed nitrite concentration in meat products is 200 ppm.

Under certain conditions - especially during cooking - nitrites in meat can react with degradation products of amino acids, forming nitrosamines, which are known carcinogens.

Nitrite is detected and analyzed by the Griess Reaction, involving the formation of a deep red-colored azo dye upon treatment of a NO_2^- -containing sample with sulfanilic acid and naphthyl-1-amine in the presence of acid. Nitrite can be reduced to nitric oxide or ammonia by many species of bacteria.

Under hypoxic conditions, nitrite may release nitric oxide, which causes potent vasodilation. Several mechanisms for nitrite conversion to NO have been described, including enzymatic reduction by xanthine oxidoreductase, nitrite reductase, and NO synthase (NOS), as well as nonenzymatic acidic disproportionation reactions.

Organic Nitrites and Nitro Compounds



Aromatic Nitration

In organic chemistry, nitrites are esters of nitrous acid and contain the nitrosoxy functional group. Nitro compounds contain the $\text{C}-\text{NO}_2$ group. Nitrites have the general formula RONO , where R is an aryl or alkyl group. Nitrobenzene is a simple example of a nitro compound. In aromatic nitration reactions a $\text{C}-\text{H}$ bond is broken, leaving the two electrons on the carbon atom. These two electrons are added to the nitronium ion, reducing it to nitrite.

↓

Selenium- Inorganic Contaminant 0.05 mg/L Water MCL

Selenium (Se) is an essential element for human nutrition, with the majority of our intake coming from foods such as nuts, cereals, meat, fish, and eggs. The concentration of Selenium in drinking water is usually low, and comes from natural minerals. In soils, selenium often occurs in soluble forms such as selenate, which are leached into rivers very easily by runoff increasing the amount of selenium in groundwater. Selenium in water is also a by-product of copper mining / smelting. Selenium is also used in photoelectric devices because its electrical conductivity varies with light.

Naturally occurring selenium compounds have not been shown to be carcinogenic in animals. However, acute toxicity caused by high levels of selenium in water or other sources of intake has been observed in laboratory animals and in animals grazing in areas where high selenium levels exist in the soil. The US EPA has established the MCL for selenium in water at 0.05 mg/l.



What are selenium's health effects?

Some people who drink water containing selenium well in excess of the maximum contaminant level (MCL) for many years could experience hair or fingernail losses, numbness in fingers or toes, or problems with their circulation.

This health effects language is not intended to catalog all possible health effects for selenium. Rather, it is intended to inform consumers of some of the possible health effects associated with selenium in drinking water when the rule was finalized.

What are EPA's drinking water regulations for selenium?

In 1974, Congress passed the Safe Drinking Water Act. This law requires EPA to determine the level of contaminants in drinking water at which no adverse health effects are likely to occur. These non-enforceable health goals, based solely on possible health risks and exposure over a lifetime with an adequate margin of safety, are called maximum contaminant level goals (MCLG). Contaminants are any physical, chemical, biological or radiological substances or matter in water.

The MCLG for selenium is 0.05 mg/L or 50 ppb. EPA has set this level of protection based on the best available science to prevent potential health problems. EPA has set an enforceable regulation for selenium, called a maximum contaminant level (MCL), at 0.05 mg/L or 50 ppb. MCLs are set as close to the health goals as possible, considering cost, benefits and the ability of public water systems to detect and remove contaminants using suitable treatment technologies. In this case, the MCL equals the MCLG, because analytical methods or treatment technology do not pose any limitation.

The Phase II Rule, the regulation for selenium, became effective in 1992. The Safe Drinking Water Act requires EPA to periodically review the national primary drinking water regulation for each contaminant and revise the regulation, if appropriate. EPA reviewed selenium as part of the Six Year Review and determined that the 0.05 mg/L or 50 ppb MCLG and 0.05 mg/L or 50 ppb MCL for selenium are still protective of human health.

Selenium Water Treatment

Selenium contamination of water systems may result whenever new agricultural runoff courses through normally dry undeveloped lands. If you have high levels of selenium in your water the following are recommended selenium water treatment options. Anion exchange can reduce the amount of selenium in drinking water by 60 - 95%. Reverse Osmosis Systems are excellent at removing selenium in drinking water.

Selenium shows borderline metalloid or nonmetal behavior. Its most stable form, the grey trigonal allotrope, is sometimes called 'metallic' selenium. This is because its electrical conductivity is several orders of magnitude greater than that of the red monoclinic form.

The metallic character of selenium is further shown by the following properties:

- Its luster.
- Its crystalline structure, which is thought to include weakly 'metallic' interchain bonding.
- Its capacity, when molten, to be drawn into thin threads.
- Its reluctance to acquire 'the high positive oxidation numbers characteristic of nonmetals'.
- Its capacity to form cyclic polycations (such as Se_2^{+8}) when dissolved in oleums (an attribute it shares with sulfur and tellurium).
- The existence of a hydrolyzed cationic salt in the form of trihydroxoselenium (IV) perchlorate $[\text{Se}(\text{OH})_3]^+ \cdot \text{ClO}_4^-$.

The Non-metallic Character of Selenium is shown by:

- Its brittleness.
- Its electronic band structure, which is that of a semiconductor.
- The low electrical conductivity ($\sim 10^{-9}$ to $10^{-12} \text{ S} \cdot \text{cm}^{-1}$) of its highly purified form. This is comparable to or less than that of bromine ($7.95 \times 10^{-12} \text{ S} \cdot \text{cm}^{-1}$), a nonmetal.
- Its relatively high electronegativity (2.55 revised Pauling scale).
- The retention of its semiconducting properties in liquid form.
- Its reaction chemistry, which is mainly that of its nonmetallic anionic forms Se^{2-} , SeO_2^{3-} and SeO_2^{4-} .

Selenium Explained

Selenium is a chemical element with symbol **Se** and atomic number 34. It is a nonmetal with properties that are intermediate between those of its periodic table column-adjacent chalcogen elements sulfur and tellurium. It rarely occurs in its elemental state in nature, or as pure ore compounds. Selenium (Greek σελήνη *selene* meaning "Moon") was discovered in 1817 by Jöns Jakob Berzelius, who noted the similarity of the new element to the previously-known tellurium (named for the Earth).

Selenium is found impurely in metal sulfide ores, where it partially replaces the sulfur. Commercially, selenium is produced as a byproduct in the refining of these ores, most often during copper production.

Minerals that are pure selenide or selenate compounds are known, but are rare. The chief commercial uses for selenium today are in glassmaking and in pigments. Selenium is a semiconductor and is used in photocells. Uses in electronics, once important, have been mostly supplanted by silicon semiconductor devices. Selenium continues to be used in a few types of DC power surge protectors and one type of fluorescent quantum dot.

Selenium salts are toxic in large amounts, but trace amounts are necessary for cellular function in many organisms, including all animals. Selenium is a component of the antioxidant enzymes glutathione peroxidase and thioredoxin reductase (which indirectly reduce certain oxidized molecules in animals and some plants). It is also found in three deiodinase enzymes, which convert one thyroid hormone to another. Selenium requirements in plants differ by species, with some plants requiring relatively large amounts, and others apparently requiring none.

Characteristics

Physical Properties

Selenium exists in several allotropes that interconvert upon heating and cooling carried out at different temperatures and rates. As prepared in chemical reactions, selenium is usually amorphous, brick-red powder. When rapidly melted, it forms the black, vitreous form, which is usually sold industrially as beads. The structure of black selenium is irregular and complex and consists of polymeric rings with up to 1000 atoms per ring. Black Se is a brittle, lustrous solid that is slightly soluble in CS₂. Upon heating, it softens at 50 °C and converts to gray selenium at 180 °C; the transformation temperature is reduced by presence of halogens and amines.

The red-colored α , β and γ forms are produced from solutions of black selenium by varying evaporation rates of the solvent (usually CS₂). They all have relatively low, monoclinic crystal symmetries and contain nearly identical puckered Se₈ rings arranged in different fashions, as in sulfur. The packing is most dense in the α form. In the Se₈ rings, the Se-Se distance is 233.5 pm and Se-Se-Se angle is 105.7 degrees. Other selenium allotropes may contain Se₆ or Se₇ rings.

The most stable and dense form of selenium has a gray color and hexagonal crystal lattice consisting of helical polymeric chains, wherein the Se-Se distance is 237.3 pm and Se-Se-Se angle is 130.1 degrees. The minimum distance between chains is 343.6 pm. Gray Se is formed by mild heating of other allotropes, by slow cooling of molten Se, or by condensing Se vapors just below the melting point. Whereas other Se forms are insulators, gray Se is a semiconductor showing appreciable photoconductivity. Contrary to other allotropes, it is insoluble in CS₂. It resists oxidation by air and is not attacked by non-oxidizing acids. With strong reducing agents, it forms polyselenides. Selenium does not exhibit the unusual changes in viscosity that sulfur undergoes when gradually heated.

Isotopes

Selenium has six naturally occurring isotopes, five of which are stable: ^{74}Se , ^{76}Se , ^{77}Se , ^{78}Se , and ^{80}Se . The last three also occur as fission products, along with ^{79}Se , which has a half-life of 327,000 years. The final naturally occurring isotope, ^{82}Se , has a very long half-life ($\sim 10^{20}$ yr, decaying via double beta decay to ^{82}Kr), which, for practical purposes, can be considered to be stable. Twenty-three other unstable isotopes have been characterized.

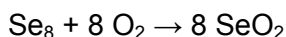
See also *Selenium-79* for more information on recent changes in the measured half-life of this long-lived fission product, important for the dose calculations performed in the frame of the geological disposal of long-lived radioactive waste.

Chemical Compounds

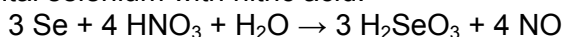
Selenium compounds commonly exist in the oxidation states -2, +2, +4, and +6.

Chalcogen Compounds

Selenium forms two oxides: selenium dioxide (SeO_2) and selenium trioxide (SeO_3). Selenium dioxide is formed by the reaction of elemental selenium with oxygen:



It is a polymeric solid that forms monomeric SeO_2 molecules in the gas phase. It dissolves in water to form selenous acid, H_2SeO_3 . Selenous acid can also be made directly by oxidizing elemental selenium with nitric acid:



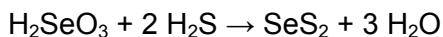
Unlike sulfur, which forms a stable trioxide, selenium trioxide is thermodynamically unstable and decomposes to the dioxide above 185 °C:



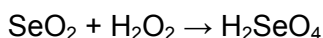
Selenium trioxide is produced in the laboratory by the reaction of anhydrous potassium selenate (K_2SeO_4) and sulfur trioxide (SO_3).

Salts of selenous acid are called *selenites*. These include silver selenite (Ag_2SeO_3) and sodium selenite (Na_2SeO_3).

Hydrogen sulfide reacts with aqueous selenous acid to produce selenium disulfide:



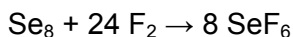
Selenium disulfide consists of 8-membered rings of a nearly statistical distribution of sulfur and selenium atoms. It has an approximate composition of SeS_2 , with individual rings varying in composition, such as Se_4S_4 and Se_2S_6 . Selenium disulfide has been used in shampoo as an anti-dandruff agent, an inhibitor in polymer chemistry, a glass dye, and a reducing agent in fireworks. Selenium trioxide may be synthesized by dehydrating selenic acid, H_2SeO_4 , which is itself produced by the oxidation of selenium dioxide with hydrogen peroxide:



Hot, concentrated selenic acid is capable of dissolving gold, forming gold(III) selenate.

Halogen Compounds

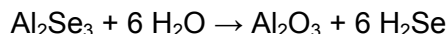
Iodides of selenium are not well known. The only stable chloride is selenium monochloride (Se_2Cl_2), which might be better known as selenium(I) chloride; the corresponding bromide is also known. These species are structurally analogous to the corresponding disulfur dichloride. Selenium dichloride is an important reagent in the preparation of selenium compounds (e.g. the preparation of Se_7). It is prepared by treating selenium with sulfuryl chloride (SO_2Cl_2). Selenium reacts with fluorine to form selenium hexafluoride:



In comparison with its sulfur counterpart (sulfur hexafluoride), selenium hexafluoride (SeF_6) is more reactive and is a toxic pulmonary irritant. Some of the selenium oxyhalides, such as selenium oxyfluoride (SeOF_2) and selenium oxychloride (SeOCl_2) have been used as specialty solvents.

Selenides

Analogous to the behavior of other chalcogens, selenium forms a dihydride H_2Se . It is a strongly odiferous, toxic, and colorless gas. It is more acidic than H_2S . In solution it ionizes to HSe^- . The selenide dianion Se^{2-} forms a variety of compounds, including the minerals from which selenium is obtained commercially. Illustrative selenides include mercury selenide (HgSe), lead selenide (PbSe), zinc selenide (ZnSe), and copper indium gallium diselenide ($\text{Cu}(\text{Ga}, \text{In})\text{Se}_2$). These materials are semiconductors. With highly electropositive metals, such as aluminum, these selenides are prone to hydrolysis:

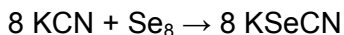


Alkali metal selenides react with selenium to form polyselenides, Se_{2-x} , which exist as chains.

Other Compounds

Tetraselenium tetranitride, Se_4N_4 , is an explosive orange compound analogous to tetrasulfur tetranitride (S_4N_4). It can be synthesized by the reaction of selenium tetrachloride (SeCl_4) with $[(\text{CH}_3)_3\text{Si})_2\text{N}]_2\text{Se}$.

Selenium reacts with cyanides to yield selenocyanates:



Organoselenium Compounds

Selenium, especially in the II oxidation state, forms stable bonds to carbon, which are structurally analogous to the corresponding organosulfur compounds. Especially common are selenides (R_2Se , analogues of thioethers), diselenides (R_2Se_2 , analogues of disulfides), and selenols (RSeH , analogues of thiols). Representatives of selenides, diselenides, and selenols include respectively selenomethionine, diphenyldiselenide, and benzeneselenol. The sulfoxide in sulfur chemistry is represented in selenium chemistry by the selenoxides (formula $\text{RSe}(\text{O})\text{R}$), which are intermediates in organic synthesis, as illustrated by the selenoxide elimination reaction. Consistent with trends indicated by the double bond rule, selenoketones, $\text{R}(\text{C}=\text{Se})\text{R}$, and selenaldehydes, $\text{R}(\text{C}=\text{Se})\text{H}$, are rarely observed.

History

Selenium (Greek σελήνη *selene* meaning "Moon") was discovered in 1817 by Jöns Jakob Berzelius and Johan Gottlieb Gahn. Both chemists owned a chemistry plant near Gripsholm, Sweden producing sulfuric acid by the lead chamber process. The pyrite from the Falun mine created a red precipitate in the lead chambers which was presumed to be an arsenic compound, and so the pyrite's use to make acid was discontinued. Berzelius and Gahn wanted to use the pyrite and they also observed that the red precipitate gave off a smell like horseradish when burned. This smell was not typical of arsenic, but a similar odor was known from tellurium compounds. Hence, Berzelius's first letter to Alexander Marcet stated that this was a tellurium compound. However, the lack of tellurium compounds in the Falun mine minerals eventually led Berzelius to reanalyze the red precipitate, and in 1818 he wrote a second letter to Marcet describing a newly found element similar to sulfur and tellurium. Because of its similarity to tellurium, named for the Earth, Berzelius named the new element after the Moon.

In 1873, Willoughby Smith found that the electrical resistance of grey selenium was dependent on the ambient light. This led to its use as a cell for sensing light. The first of commercial products using selenium were developed by Werner Siemens in the mid-1870s. The selenium cell was used in the photophone developed by Alexander Graham Bell in 1879. Selenium transmits an electric current proportional to the amount of light falling on its surface. This phenomenon was used in the design of light meters and similar devices. Selenium's semiconductor properties found numerous other applications in electronics. The development of selenium rectifiers began during the early 1930s, and these replaced copper oxide rectifiers because of their superior efficiencies. These lasted in commercial applications until the 1970s, following which they were replaced with less expensive and even more efficient silicon rectifiers.

Selenium came to medical notice later because of its toxicity to human beings working in industries.

Selenium was also recognized as an important veterinary toxin, which is seen in animals that have eaten high-selenium plants. In 1954, the first hints of specific biological functions of selenium were discovered in microorganisms. Its essentiality for mammalian life was discovered in 1957. In the 1970s, it was shown to be present in two independent sets of enzymes. This was followed by the discovery of selenocysteine in proteins.

Occurrence

Native (i.e., elemental) selenium is a rare mineral, which does not usually form good crystals, but, when it does, they are steep rhombohedra or tiny acicular (hair-like) crystals. Isolation of selenium is often complicated by the presence of other compounds and elements.

Selenium occurs naturally in a number of inorganic forms, including selenide-, selenate-, and selenite-containing minerals, but these minerals are rare. The common mineral selenite is *not* a selenium mineral, and contains no selenite ion, but is rather a type of gypsum (calcium sulfate hydrate) named like selenium for the moon well before the discovery of selenium. Selenium is most commonly found quite impurely, replacing a small part of the sulfur in sulfide ores of many metals.

In living systems, selenium is found in the amino acids selenomethionine, selenocysteine, and methylselenocysteine. In these compounds, selenium plays a role analogous to that of sulfur. Another naturally occurring organoselenium compound is dimethyl selenide.

Certain solids are selenium-rich, and selenium can be bioconcentrated by certain plants. In soils, selenium most often occurs in soluble forms such as selenate (analogous to sulfate), which are leached into rivers very easily by runoff. Ocean water contains significant amounts of selenium.

Anthropogenic sources of selenium include coal burning and the mining and smelting of sulfide ores.

Production

Selenium is most commonly produced from selenide in many sulfide ores, such as those of copper, silver, or lead. Electrolytic metal refining is particularly conducive to producing selenium as a byproduct, and it is obtained from the anode mud of copper refineries. Another source was the mud from the lead chambers of sulfuric acid plants but this method to produce sulfuric acid is no longer used.

These muds can be processed by a number of means to obtain selenium. However, most elemental selenium comes as a byproduct of refining copper or producing sulfuric acid.

Since the invention of solvent extraction and electrowinning (SX/EW) for the production of copper this method takes an increasing share of the world wide copper production. This changes the availability of selenium because only a comparably small part of the selenium in the ore is leached together with the copper.

Industrial production of selenium usually involves the extraction of selenium dioxide from residues obtained during the purification of copper. Common production from the residue then begins by oxidation with sodium carbonate to produce selenium dioxide. The selenium dioxide is then mixed with water and the solution is acidified to form selenous acid (oxidation step). Selenous acid is bubbled with sulfur dioxide (reduction step) to give elemental selenium.

Toxicity

Although selenium is an essential trace element, it is toxic if taken in excess. Exceeding the Tolerable Upper Intake Level of 400 micrograms per day can lead to selenosis. This 400 microgram (μg) Tolerable Upper Intake Level is based primarily on a 1986 study of five Chinese patients who exhibited overt signs of selenosis and a follow up study on the same five people in 1992.

The 1992 study actually found the maximum safe dietary Se intake to be approximately 800 micrograms per day (15 micrograms per kilogram body weight), but suggested 400 micrograms per day to not only avoid toxicity, but also to avoid creating an imbalance of nutrients in the diet and to account for data from other countries. In China, people who ingested corn grown in extremely selenium-rich stony coal (carbonaceous shale) have suffered from selenium toxicity. This coal was shown to have selenium content as high as 9.1%, the highest concentration in coal ever recorded in literature.

Symptoms of selenosis include a garlic odor on the breath, gastrointestinal disorders, hair loss, sloughing of nails, fatigue, irritability, and neurological damage. Extreme cases of selenosis can result in cirrhosis of the liver, pulmonary edema, and death. Elemental selenium and most metallic selenides have relatively low toxicities because of their low bioavailability. By contrast, selenates and selenites are very toxic, having an oxidant mode of action similar to that of arsenic trioxide. The chronic toxic dose of selenite for humans is about 2400 to 3000 micrograms of selenium per day for a long time. Hydrogen selenide is an extremely toxic, corrosive gas. Selenium also occurs in organic compounds, such as dimethyl selenide, selenomethionine, selenocysteine and methylselenocysteine, all of which have high bioavailability and are toxic in large doses.

In fish and other wildlife, low levels of selenium cause deficiency while high levels cause toxicity. For example, in salmon, the optimal concentration of selenium in the fish tissue (whole body) is about 1 microgram selenium per gram of tissue (dry weight). At levels much below that concentration, young salmon die from selenium deficiency; much above that level they die from toxic excess.

hydrogen 1 H 1.0079																		helium 2 He 4.0026																			
lithium 3 Li 6.941		beryllium 4 Be 9.0122																		boron 5 B 10.811		carbon 6 C 12.011		nitrogen 7 N 14.007		oxygen 8 O 15.999		fluorine 9 F 18.998		neon 10 Ne 20.180							
sodium 11 Na 22.990		magnesium 12 Mg 24.305																		aluminum 13 Al 26.982		silicon 14 Si 28.086		phosphorus 15 P 30.974		sulfur 16 S 32.065		chlorine 17 Cl 35.453		argon 18 Ar 39.948							
potassium 19 K 39.098		calcium 20 Ca 40.078		scandium 21 Sc 44.956		titanium 22 Ti 47.867		vanadium 23 V 50.942		chromium 24 Cr 51.996		manganese 25 Mn 54.938		iron 26 Fe 55.845		cobalt 27 Co 58.933		nickel 28 Ni 58.693		copper 29 Cu 63.546		zinc 30 Zn 65.39		gallium 31 Ga 69.723		germanium 32 Ge 72.61		arsenic 33 As 74.922		selenium 34 Se 78.96		bromine 35 Br 79.904		krypton 36 Kr 83.80			
rubidium 37 Rb 85.468		strontium 38 Sr 87.62		yttrium 39 Y 88.906		zirconium 40 Zr 91.224		niobium 41 Nb 92.906		molybdenum 42 Mo 95.94		technetium 43 Tc [98]		ruthenium 44 Ru 101.07		rhodium 45 Rh 102.91		palladium 46 Pd 106.42		silver 47 Ag 107.87		cadmium 48 Cd 112.41		indium 49 In 114.82		tin 50 Sn 118.71		antimony 51 Sb 121.76		tellurium 52 Te 127.60		iodine 53 I 126.90		xenon 54 Xe 131.29			
cesium 55 Cs 132.91		barium 56 Ba 137.33		57-70 *		lutetium 71 Lu 174.97		hafnium 72 Hf 178.49		tantalum 73 Ta 180.95		tungsten 74 W 183.84		rhenium 75 Re 186.21		osmium 76 Os 190.23		iridium 77 Ir 192.22		platinum 78 Pt 195.08		gold 79 Au 196.97		mercury 80 Hg 200.59		thallium 81 Tl 204.38		lead 82 Pb 207.2		bismuth 83 Bi 208.98		polonium 84 Po [209]		astatine 85 At [210]		radon 86 Rn [222]	
francium 87 Fr [223]		radium 88 Ra [226]		89-102 * *		lawrencium 103 Lr [262]		rutherfordium 104 Rf [261]		dubnium 105 Db [262]		seaborgium 106 Sg [266]		bohrium 107 Bh [264]		hassium 108 Hs [269]		meitnerium 109 Mt [268]		ununnium 110 Uun [271]		ununium 111 Uuu [272]		unubium 112 Uub [277]													
												ununquadium 114 Uuq [289]																									

* Lanthanide series

lanthanum 57 La 138.91	cerium 58 Ce 140.12	praseodymium 59 Pr 140.91	neodymium 60 Nd 144.24	promethium 61 Pm [145]	samarium 62 Sm 150.36	europium 63 Eu 151.96	gadolinium 64 Gd 157.25	terbium 65 Tb 158.93	dysprosium 66 Dy 162.50	holmium 67 Ho 164.93	erbium 68 Er 167.26	thulium 69 Tm 168.93	ytterbium 70 Yb 173.04
actinium 89 Ac [227]	thorium 90 Th 232.04	protactinium 91 Pa 231.04	uranium 92 U 238.03	neptunium 93 Np [237]	plutonium 94 Pu [244]	americium 95 Am [243]	curium 96 Cm [247]	berkelium 97 Bk [247]	californium 98 Cf [251]	einsteinium 99 Es [252]	fermium 100 Fm [257]	mendelevium 101 Md [258]	nobelium 102 No [259]

* * Actinide series

Thallium- Inorganic Contaminant 0.002 mg/L Water MCL

Thallium is a metal found in natural deposits such as ores containing other elements.

Uses for Thallium.

The greatest use of thallium is in specialized electronic research equipment.

What are Thallium's Health Effects?

Some people who drink water containing thallium well in excess of the maximum contaminant level (MCL) for many years could experience hair loss, changes in their blood, or problems with their kidneys, intestines, or liver problems.

This health effects language is not intended to catalog all possible health effects for thallium. Rather, it is intended to inform consumers of some of the possible health effects associated with thallium in drinking water when the rule was finalized.



What are EPA's Drinking Water Regulations for Thallium?

In 1974, Congress passed the Safe Drinking Water Act. This law requires EPA to determine the level of contaminants in drinking water at which no adverse health effects are likely to occur. These non-enforceable health goals, based solely on possible health risks and exposure over a lifetime with an adequate margin of safety, are called maximum contaminant level goals (MCLG). Contaminants are any physical, chemical, biological or radiological substances or matter in water.

The MCLG for thallium is 0.0005 mg/L or 0.5 ppb. EPA has set this level of protection based on the best available science to prevent potential health problems. EPA has set an enforceable regulation for thallium, called a maximum contaminant level (MCL), at 0.002 mg/L or 2 ppb. MCLs are set as close to the health goals as possible, considering cost, benefits and the ability of public water systems to detect and remove contaminants using suitable treatment technologies.

The Phase V Rule, the regulation for thallium, became effective in 1994. The Safe Drinking Water Act requires EPA to periodically review the national primary drinking water regulation for each contaminant and revise the regulation, if appropriate. EPA reviewed thallium as part of the Six Year Review and determined that the 0.0005 mg/L or 0.5 ppb MCLG and 0.002 mg/L or 2 ppb MCL for thallium are still protective of human health. States may set more stringent drinking water MCLGs and MCLs for thallium than EPA.

How does Thallium get into my Drinking Water?

The major sources of thallium in drinking water are leaching from ore-processing sites; and discharge from electronics, glass, and drug factories.

A federal law called the Emergency Planning and Community Right to Know Act (EPCRA) requires facilities in certain industries, which manufacture, process, or use significant amounts of toxic chemicals, to report annually on their releases of these chemicals. For more information on the uses and releases of chemicals in your state, contact the Community Right-to-Know Hotline: (800) 424-9346.

How will I know if Thallium is in my Drinking Water?

When routine monitoring indicates that thallium levels are above the MCL, your water supplier must take steps to reduce the amount of thallium so that it is below that level. Water suppliers must notify their customers as soon as practical, but no later than 30 days after the system learns of the violation. Additional actions, such as providing alternative drinking water supplies, may be required to prevent serious risks to public health.

How will Thallium be Removed from my Drinking Water?

The following treatment method(s) have proven to be effective for removing thallium to below 0.002 mg/L or 2 ppb: activated alumina; ion exchange.

How do I learn more about my Drinking Water?

EPA strongly encourages people to learn more about their drinking water, and to support local efforts to protect the supply of safe drinking water and upgrade the community water system. Your water bill or telephone book's government listings are a good starting point for local information.

Contact your water utility. EPA requires all community water systems to prepare and deliver an annual consumer confidence report (CCR) (sometimes called a water quality report) for their customers by July 1 of each year. If your water provider is not a community water system, or if you have a private water supply, request a copy from a nearby community water system.

Thallium Explained

Thallium is a chemical element with symbol **Tl** and atomic number 81. This soft gray poor metal is not found free in nature. When isolated, it resembles tin, but discolors when exposed to air. Chemists William Crookes and Claude-Auguste Lamy discovered thallium independently in 1861, in residues of sulfuric acid production. Both used the newly developed method of flame spectroscopy, in which thallium produces a notable green spectral line. Thallium, from Greek *θαλλός*, *thallos*, meaning "a green shoot or twig," was named by Crookes. It was isolated by electrolysis a year later, by Lamy.

Thallium tends to oxidize to the +3 and +1 oxidation states as ionic salts. The +3 state resembles that of the other elements in thallium's group (boron, aluminum, gallium, indium). However, the +1 state, which is far more prominent in thallium than the elements above it, recalls the chemistry of alkali metals, and thallium(I) ions are found geologically mostly in potassium-based ores, and (when ingested) are handled in many ways like potassium ions (K^+) by ion pumps in living cells.

Commercially, however, thallium is produced not from potassium ores, but as a byproduct from refining of heavy metal sulfide ores. Approximately 60–70% of thallium production is used in the electronics industry, and the remainder is used in the pharmaceutical industry and in glass manufacturing. It is also used in infrared detectors. The radioisotope thallium-201 (as the soluble chloride $TlCl$) is used in small, nontoxic amounts as an agent in a nuclear medicine scan, during one type of nuclear cardiac stress test.

Soluble thallium salts (many of which are nearly tasteless) are highly toxic in quantity, and were historically used in rat poisons and insecticides. Use of these compounds has been restricted or banned in many countries, because of their nonselective toxicity.

Thallium poisoning notably results in hair loss. Because of its historic popularity as a murder weapon, thallium has gained notoriety as "the poisoner's poison" and "inheritance powder" (alongside arsenic).

Characteristics

Thallium is extremely soft, malleable and sectile enough to be cut with a knife at room temperature. It has a metallic luster that, when exposed to air, quickly tarnishes to a bluish-gray tinge, resembling lead. It may be preserved by immersion in oil. A heavy layer of oxide builds up on thallium if left in air. In the presence of water, thallium hydroxide is formed. Sulfuric and nitric acid dissolve thallium rapidly to make the sulfate and nitrate salts, while hydrochloric acid forms an insoluble thallium(I) chloride layer. Its standard electrode potential is -0.34 , slightly higher than the potential for iron (at -0.44).

Isotopes

Thallium has 25 isotopes which have atomic masses that range from 184 to 210. ^{203}Tl and ^{205}Tl are the only stable isotopes, and ^{204}Tl is the most stable radioisotope, with a half-life of 3.78 years.

^{202}Tl (half-life 12.23 days) can be made in a cyclotron, while ^{204}Tl is made by the neutron activation of stable thallium in a nuclear reactor.

^{201}Tl (half-life 73 hrs), decays by electron capture, emitting Hg X-rays (~ 70 – 80 keV), and photons of 135 and 167 keV in 10% total abundance; therefore it has good imaging characteristics without excessive patient radiation dose. It is the most popular isotope used for thallium nuclear cardiac stress tests.

^{208}Tl (half-life 3.05 minutes) is generated in the naturally-occurring thorium decay chain. Its prominent 2615 keV gamma ray is the dominant high-energy feature observed in natural background radiation.

Chemistry

The two main oxidation states of thallium are +1 and +3. In the oxidation state +1 most compounds closely resemble the corresponding potassium or silver compounds (the ionic radius of thallium(I) is 1.47 Å while that of potassium is 1.33 Å and that of silver is 1.26 Å), which was the reason why thallium was sometimes considered to be an alkali metal in Europe (but not in England) in the years immediately following its discovery.¹²⁶ For example, the water-soluble and very basic thallium(I) hydroxide reacts with carbon dioxide forming water-soluble thallium carbonate. This carbonate is the only water soluble heavy metal carbonate. The similarity with silver compounds is observed with the halide, oxide, and sulfide compounds. Thallium(I) bromide is a photosensitive yellow compound very similar to the silver bromide, while the black thallium(I) oxide and thallium(I) sulfide are very similar to the silver oxide and silver sulfide.

The compounds with oxidation state +3 resemble the corresponding aluminum (III) compounds. They are moderately strong oxidizing agents, as illustrated by the reduction potential of $+0.72$ volts for $\text{Tl}^{3+} + 3\text{e}^- \rightarrow \text{Tl(s)}$. The thallium(III) oxide is a black solid which decomposes above 800 °C, forming the thallium(I) oxide and oxygen.

History

Thallium (Greek *θαλλός*, *thallos*, meaning "a green shoot or twig") was discovered by flame spectroscopy in 1861. The name comes from thallium's bright green spectral emission lines.

After the publication of the improved method of flame spectroscopy by Robert Bunsen and Gustav Kirchhoff and the discovery of caesium and rubidium in the years 1859 to 1860, flame spectroscopy became an approved method to determine the composition of minerals and chemical products.

William Crookes and Claude-Auguste Lamy both started to use the new method. William Crookes used it to make spectroscopic determinations for tellurium on selenium compounds deposited in the lead chamber of a sulfuric acid production plant near Tilkerode in the Harz mountains. He had obtained the samples for his research on selenium cyanide from August Hofmann years earlier. By 1862, Crookes was able to isolate small quantities of the new element and determine the properties of a few compounds. Claude-Auguste Lamy used a spectrometer that was similar to Crookes' to determine the composition of a selenium-containing substance which was deposited during the production of sulfuric acid from pyrite. He also noticed the new green line in the spectra and concluded that a new element was present. Lamy had received this material from the sulfuric acid plant of his friend Fréd Kuhlmann and this by-product was available in large quantities. Lamy started to isolate the new element from that source.

The fact that Lamy was able to work ample quantities of thallium enabled him to determine the properties of several compounds and in addition he prepared a small ingot of metallic thallium which he prepared by remelting thallium he had obtained by electrolysis of thallium salts.

As both scientists discovered thallium independently and a large part of the work, especially the isolation of the metallic thallium was done by Lamy, Crookes tried to secure his priority on the work. Lamy was awarded a medal at the International Exhibition in London 1862: *For the discovery of a new and abundant source of thallium* and after heavy protest Crookes also received a medal: *thallium, for the discovery of the new element*. The controversy between both scientists continued through 1862 and 1863. Most of the discussion ended after Crookes was elected Fellow of the Royal Society in June 1863.

The dominant use of thallium was the use as poison for rodents. After several accidents the use as poison was banned in the United States by the Presidential Executive Order 11643 in February 1972. In the subsequent years several other countries also banned the use.

Occurrence and Production

Although thallium is a modestly abundant element in the Earth's crust, with a concentration estimated to be about 0.7 mg/kg, mostly in association with potassium-based minerals in clays, soils, and granites, thallium is not generally economically recoverable from these sources. The major source of thallium for practical purposes is the trace amount that is found in copper, lead, zinc, and other heavy-metal-sulfide ores.

Thallium is found in the minerals crookesite TiCu_7Se_4 , hutchinsonite $\text{TiPbAs}_5\text{S}_9$, and lorandite TiAsS_2 . Thallium also occurs as a trace element in iron pyrite, and thallium is extracted as a by-product of roasting this mineral for the production of sulfuric acid.

Thallium can also be obtained from the smelting of lead and zinc ores. Manganese nodules found on the ocean floor also contain some thallium, but the collection of these nodules has been and continues to be prohibitively expensive.

There is also the potential for damaging the environment of the oceans. In addition, several other thallium minerals, containing 16% to 60% thallium, occur in nature as complexes of sulfides or selenides that primarily contain antimony, arsenic, copper, lead, and/or silver. However, these minerals are rare, and they have had no commercial importance as sources of thallium. The Allchar deposit in southern Macedonia was the only area where thallium was ever actively mined. This deposit still contains a loosely estimated 500 tons of thallium, and it is a source for several rare thallium minerals, for example lorandite.

The United States Geological Survey (USGS) estimates that the annual worldwide production of thallium is about 10 metric tons as a by-product from the smelting of copper, zinc, and lead ores. Thallium is either extracted from the dusts from the smelter flues or from residues such as slag that are collected at the end of the smelting process. The raw materials used for thallium production contain large amounts of other materials and therefore a purification is the first step.

The thallium is leached either by the use of a base or sulfuric acid from the material. The thallium is several times precipitated from the solution and to remove further impurities. At the end it is converted to thallium sulfate and the thallium is extracted by electrolysis on platinum or stainless steel plates. The production of thallium decreased by about 33% in the period from 1995 to 2009 – from about 15 metric tons to about 10 tons. Since there are several small deposits or ores with relatively high thallium content, it would be possible to increase the production of it if a new application, such as a hypothetical thallium-containing high-temperature superconductor, becomes practical for widespread use outside of the laboratory.

Applications

Historic Uses

The odorless and tasteless thallium sulfate was once widely used as rat poison and ant killer. Since 1972 this use has been prohibited in the United States due to safety concerns. Many other countries followed this example in the following years. Thallium salts were used in the treatment of ringworm, other skin infections and to reduce the night sweating of tuberculosis patients. However this use has been limited due to their narrow therapeutic index, and the development of more-advanced medicines for these conditions.

Optics

Thallium(I) bromide and thallium(I) iodide crystals have been used as infrared optical materials, because they are harder than other common infrared optics, and because they have transmission at significantly longer wavelengths. The trade name KRS-5 refers to this material.

Thallium(I) oxide has been used to manufacture glasses that have a high index of refraction. Combined with sulfur or selenium and arsenic, thallium has been used in the production of high-density glasses that have low melting points in the range of 125 and 150 °C. These glasses have room temperature properties that are similar to ordinary glasses and are durable, insoluble in water and have unique refractive indices.

Electronics

Thallium(I) sulfide's electrical conductivity changes with exposure to infrared light therefore making this compound useful in photoresistors. Thallium selenide has been used in a bolometer for infrared detection. Doping selenium semiconductors with thallium improves their performance, and therefore it is used in trace amounts in selenium rectifiers. Another application of thallium doping is the sodium iodide crystals in gamma radiation detection devices.

In these, the sodium iodide crystals are doped with a small amount of thallium to improve their efficiency as scintillation generators. Some of the electrodes in dissolved oxygen analyzers contain thallium.

High-Temperature Superconductivity

Research activity with thallium is ongoing to develop high-temperature superconducting materials for such applications as magnetic resonance imaging, storage of magnetic energy, magnetic propulsion, and electric power generation and transmission. The research in applications started after the discovery of the first thallium barium calcium copper oxide superconductor in 1988.

Other Uses

A mercury-thallium alloy, which forms a eutectic at 8.5% thallium, is reported to freeze at $-60\text{ }^{\circ}\text{C}$, some $20\text{ }^{\circ}\text{C}$ below the freezing point of mercury. This alloy is used in thermometers and low-temperature switches. In organic synthesis thallium(III) salts, as thallium trinitrate or triacetate, are useful reagents performing different transformations in aromatics, ketones, olefins, among others. Thallium is a constituent of the alloy in the anode plates in magnesium seawater batteries. Soluble thallium salts are added to gold plating baths to increase the speed of plating and to reduce grain size within the gold layer.

The saturated solution of equal parts of thallium(I) formate ($\text{TI}(\text{CHO}_2)$) and thallium(I) malonate ($\text{TI}(\text{C}_3\text{H}_3\text{O}_4)$) in water is known as Clerici solution. It is a mobile odorless liquid whose color changes from yellowish to clear upon reducing the concentration of the thallium salts. With the density of 4.25 g/cm^3 at $20\text{ }^{\circ}\text{C}$, Clerici solution is one of the heaviest aqueous solutions known. It was used in the 20th century for measuring density of minerals by the flotation method, but the use is discontinued due to the high toxicity and corrosiveness of the solution.

Thallium iodide is used as an additive to metal halide lamps, often together with one-two halides of other metals. It allows to optimize the lamp temperature and color rendering, and shift the spectral output to the green region, which is useful for underwater lighting.

Toxicity

Thallium and its compounds are extremely toxic, and should be handled with great care. There are numerous recorded cases of fatal thallium poisoning. Contact with skin is dangerous, and adequate ventilation should be provided when melting this metal. Thallium(I) compounds have a high aqueous solubility and are readily absorbed through the skin. Exposure to them should not exceed 0.1 mg per m^2 of skin in an 8-hour time-weighted average (40-hour work week).

Thallium is a suspected human carcinogen. For a long time thallium compounds were easily available as rat poison. This fact and that it is water soluble and nearly tasteless led to frequent intoxications caused by accident or criminal intent.

Treatment and Internal Decontamination

One of the main methods of removing thallium (both radioactive and normal) from humans is to use Prussian blue, which is a material which absorbs thallium. Up to 20 g per day of Prussian blue is fed by mouth to the person, and it passes through their digestive system and comes out in the stool. Hemodialysis and hemoperfusion are also used to remove thallium from the blood serum. At later stage of the treatment additional potassium is used to mobilize thallium from the tissue.

Thallium Pollution

According to the United States Environmental Protection Agency (EPA), man-made sources of thallium pollution include gaseous emission of cement factories, coal burning power plants, and metal sewers. The main source of elevated thallium concentrations in water is the leaching of thallium from ore processing operations.

Organic chemicals that are regulated in drinking water are a group of human-made chemical compounds and are components of a variety of pesticides and industrial and commercial products, including degreasers, paints, and petroleum distillates.



SOC Section



Common water sampling bottles.

SOC/VOC bottles are the smaller, thin bottles with the septum tops. Be careful not to get any air bubbles in the SOC/VOC bottles and this may take a few weeks to learn to collect a proper sample.

SOC Introduction

Synthetic Organic Chemicals (SOCs) are organic (carbon based) chemicals that are less volatile than Volatile Organic Compounds (VOCs). SOCs are used as pesticides, defoliants, fuel additives and as ingredients for other organic compounds. They are all man made and do not naturally occur in the environment. Some of the more well-known SOCs are Atrazine, 2,4-D, Dioxin and Polychlorinated Biphenyls (PCBs).

SOCs most often enter the natural environment through application of pesticide (including runoff from areas where they are applied), as part of a legally discharged waste stream, improper or illegal waste disposal, accidental releases or as a byproduct of incineration. Some SOCs are very persistent in the environment, whether in soil or water.

SOCs are generally toxic and can have substantial health impacts from both acute (short-term) and chronic (long-term) exposure. Many are known carcinogens (cancer causing). EPA has set Maximum Contaminant Levels (MCL) for 30 SOC's under the Safe Drinking Water Act.

The Safe Drinking Water Act requires that all water sources of all public water systems be periodically monitored for regulated SOC's. The monitoring frequency can be adjusted through a waiver if SOC's are not detected.

EPA established Maximum Contaminant Levels (MCL), Maximum Contaminant Level Goals (MCLG), monitoring requirements and best available technologies for removal for 65 chemical contaminants over a five year period as EPA gathered and analyzed occurrence and health effects data. This series of rules are known as the Chemical Phase Rules and they define regulations for three contaminant groups:

- Inorganic Chemicals (IOC),
- Synthetic Organic Chemicals (SOC), and
- Volatile Organic Chemicals (VOC).

The Chemical Phase rules provide public health protection through the reduction of chronic risks from:

- cancer;
- organ damage; and
- circulatory,
- nervous, and
- reproductive system disorders.

They also help to reduce the occurrence of Methemoglobinemia or "blue baby syndrome" from ingestion of elevated levels of nitrate or nitrite. All public water systems must monitor for Nitrate and Nitrite. Community water systems and Non-transient non-community water systems must also monitor for IOCs, SOC's, and VOC's.

This is a list of the organic chemicals—which include pesticides, industrial chemicals, and disinfection by-products—that are tested for in public water systems (those that provide water to the public), along with the maximum standard for the contaminant, and a brief description of the potential health effects associated with long-term consumption of elevated levels of the contaminants.

The federal standard for most contaminants is listed as a Maximum Contaminant Level (MCL), the lowest concentration at which that particular contaminant is believed to represent a potential health concern. Unless otherwise noted, the MCL is expressed as parts per billion (ppb). Also, because of technological limitations or other factors, it is not possible to test for some contaminants in a reliable fashion. Instead, public water systems are required to use specific Treatment Techniques (TT) that are designed to remove these particular contaminants from the water.

In addition to the chemicals listed, monitoring is done for approximately 60 organic chemicals for which MCLs have not been established. If unacceptable levels are found of these “unregulated” contaminants—based on established state health standards and an assessment of the risks they pose—the response is the same as if an MCL has been exceeded: the public water system must notify those served by the system.

Synthetic Organic Chemicals	MCL (ppb)	Potential Health Effects
Acrylamide	TT	Cancer, nervous system effects
Alachlor	2	Cancer
Aldicarb	3	Nervous system effects
Aldicarb sulfoxide	4	Nervous system effects
Aldicarb sulfone	2	Nervous system effects
Atrazine	3	Liver, kidney, lung, cardiovascular effects; possible carcinogen
Benzo(a)pyrene (PAHs)	0.2	Liver, kidney effects, possible carcinogen
Carbofuran	40	Nervous system, reproductive system effects
Chlordane	2	Cancer
2,4-D	70	Liver, kidney effects
Di(2-ethylhexyl) adipate	400	Reproductive effects
Di(2-ethylhexyl) phthalate	6	Cancer
Dibromochloro-propane (DBCP)	0.2	Cancer
Dinoseb	7	Thyroid, reproductive effects
Diquat	20	Ocular, liver, kidney effects
Endothall	100	Liver, kidney, gastrointestinal effects
Endrin	2	Liver, kidney effects
Epichlorohydrin	TT	Cancer
Ethylene dibromide (EDB)	0.05	Cancer
Glyphosate	700	Liver, kidney effects
Heptachlor	0.4	Cancer
Heptachlor epoxide	0.2	Cancer

Hexachlorobenzene	1	Cancer
Hexachlorocyclopentadiene (HEX)	50	Kidney, stomach effects
Lindane	0.2	Liver, kidney, nervous system, immune system, circulatory system effects
Methoxychlor	40	Developmental, liver, kidney, nervous system effects
Oxamyl (Vydate)	200	Kidney effects
Pentachlorophenol	1	Cancer
Picloram	500	Kidney, liver effects
Polychlorinated biphenyls (PCBs)	0.5	Cancer
Simazine	4	Body weight and blood effects, possible carcinogen
2,3,7,8-TCDD (Dioxin)	0.00003	Cancer
Toxaphene	3	Cancer
2,4,5-TP (Silvex)	50	Liver, kidney effects

Volatile Organic Compounds (VOCs)

Definitions

Volatile Organic Compounds (VOCs) – “VOCs are ground-water contaminants of concern because of very large environmental releases, human toxicity, and a tendency for some compounds to persist in and migrate with ground-water to drinking-water supply well ... In general, VOCs have high vapor pressures, low-to-medium water solubilities, and low molecular weights. Some VOCs may occur naturally in the environment, other compounds occur only as a result of manmade activities, and some compounds have both origins.” - Zogorski and others, 2006

Volatile Organic Compounds (VOCs) – “Volatile organic compounds released into the atmosphere by anthropogenic and natural emissions which are important because of their involvement in photochemical pollution.” - Lincoln and others, 1998

Volatile Organic Compounds (VOCs) – “Hydrocarbon compounds that have low boiling points, usually less than 100°C, and therefore evaporate readily. Some are gases at room temperature. Propane, benzene, and other components of gasoline are all volatile organic compounds.” - Art, 1993

Volatile Organic Compounds (VOCs) – “VOCs are organic compounds that can be isolated from the water phase of a sample by purging the water sample with inert gas, such as helium, and, subsequently, analyzed by gas chromatography. Many VOCs are human-made chemicals that are used and produced in the manufacture of paints, adhesives, petroleum products, pharmaceuticals, and refrigerants. They often are compounds of fuels, solvents, hydraulic fluids, paint thinners, and dry-cleaning agents commonly used in urban settings. VOC contamination of drinking water supplies is a human-health concern because many are toxic and are known or suspected human carcinogens.” - U.S. Geological Survey, 2005

VOCs Explained

Volatile organic compounds (VOCs) are organic chemicals that have a high vapor pressure at ordinary, room-temperature conditions. Their high vapor pressure results from a low boiling point, which causes large numbers of molecules to evaporate or sublime from the liquid or solid form of the compound and enter the surrounding air. An example is formaldehyde, with a boiling point of –19 °C (–2 °F), slowly exiting paint and getting into the air.

VOCs are numerous, varied, and ubiquitous. They include both human-made and naturally occurring chemical compounds. Most scents or odors are of VOCs. VOCs play an important role in communication between plants. Some VOCs are dangerous to human health or cause harm to the environment. Anthropogenic VOCs are regulated by law, especially indoors, where concentrations are the highest. Harmful VOCs are typically not acutely toxic, but instead have compounding long-term health effects. Because the concentrations are usually low and the symptoms slow to develop, research into VOCs and their effects is difficult.

Specific Components

Paints and Coatings

A major source of man-made VOCs are coatings, especially paints and protective coatings. Solvents are required to spread a protective or decorative film. Approximately 12 billion liters of paints are produced annually. Typical solvents are aliphatic hydrocarbons, ethyl acetate, glycol ethers, and acetone. Motivated by cost, environmental concerns, and regulation, the paint and coating industries are increasingly shifting toward aqueous solvents.

Chlorofluorocarbons and Chlorocarbons

Chlorofluorocarbons, which are banned or highly regulated, were widely used cleaning products and refrigerants. Tetrachloroethene is used widely in dry cleaning and by industry. Industrial use of fossil fuels produces VOCs either directly as products (e.g., gasoline) or indirectly as byproducts (e.g., automobile exhaust).

Benzene

One VOC that is a known human carcinogen is benzene, which is a chemical found in environmental tobacco smoke, stored fuels, and exhaust from cars in an attached garage. Benzene also has natural sources such as volcanoes and forest fires. It is frequently used to make other chemicals in the production of plastics, resins, and synthetic fibers. Benzene evaporates into the air quickly and the vapor of benzene is heavier than air allowing the compound to sink into low-lying areas. Benzene has also been known to contaminate food and water and if digested can lead to vomiting, dizziness, sleepiness, rapid heartbeat, and at high levels, even death may occur.

Methylene Chloride

Methylene chloride is another VOC that is highly dangerous to human health. It can be found in adhesive removers and aerosol spray paints and the chemical has been proven to cause cancer in animals. In the human body, methylene chloride is converted to carbon monoxide and a person will suffer the same symptoms as exposure to carbon monoxide. If a product that contains methylene chloride needs to be used the best way to protect human health is to use the product outdoors. If it must be used indoors, proper ventilation is essential to keeping exposure levels down.

Perchloroethylene

Perchloroethylene is a volatile organic compound that has been linked to causing cancer in animals. It is also suspected to cause many of the breathing related symptoms of exposure to VOC's. Perchloroethylene is used mostly in dry cleaning. Studies show that people breathe in low levels of this VOC in homes where dry-cleaned clothes are stored and while wearing dry-cleaned clothing. While dry cleaners attempt to recapture perchloroethylene in the dry cleaning process to reuse it in an effort to save money, they can't recapture it all. To avoid exposure to perchloroethylene, if a strong chemical odor is coming from clothing when picked up from the dry cleaner, do not accept them and request that less of the chemical be used as well as a complete drying of the garments.

MTBE

MTBE was banned in the US around 2004 in order to limit further contamination of drinking water aquifers primarily from leaking underground gasoline storage tanks where MTBE was used as an octane booster and oxygenated-additive.

Formaldehyde

Many building materials such as paints, adhesives, wall boards, and ceiling tiles slowly emit formaldehyde, which irritates the mucous membranes and can make a person irritated and uncomfortable. Formaldehyde emissions from wood are in the range of 0.02 – 0.04 ppm. Relative humidity within an indoor environment can also affect the emissions of formaldehyde. High relative humidity and high temperatures allow more vaporization of formaldehyde from wood-materials.

Health Risks

Respiratory, allergic, or immune effects in infants or children are associated with man-made VOCs and other indoor or outdoor air pollutants. Some VOCs, such as styrene and limonene, can react with nitrogen oxides or with ozone to produce new oxidation products and secondary aerosols, which can cause sensory irritation symptoms. Unspecified VOCs are important in the creation of smog.

Health effects include:

Eye, nose, and throat irritation; headaches, loss of coordination, nausea; damage to liver, kidney, and central nervous system. Some organics can cause cancer in animals; some are suspected or known to cause cancer in humans. Key signs or symptoms associated with exposure to VOCs include conjunctival irritation, nose and throat discomfort, headache, allergic skin reaction, dyspnea, declines in serum cholinesterase levels, nausea, emesis, epistaxis, fatigue, dizziness.

The ability of organic chemicals to cause health effects varies greatly from those that are highly toxic, to those with no known health effects. As with other pollutants, the extent and nature of the health effect will depend on many factors including level of exposure and length of time exposed. Eye and respiratory tract irritation, headaches, dizziness, visual disorders, and memory impairment are among the immediate symptoms that some people have experienced soon after exposure to some organics. At present, not much is known about what health effects occur from the levels of organics usually found in homes. Many organic compounds are known to cause cancer in animals; some are suspected of causing, or are known to cause, cancer in humans.

Reducing Exposure

To reduce exposure to these toxins, one should buy products that contain Low-VOC's or No VOC's. Only the quantity which will soon be needed should be purchased, eliminating stockpiling of these chemicals. Use products with VOC's in well ventilated areas. When designing homes and buildings, design teams can implement the best possible ventilation plans, call for the best mechanical systems available, and design assemblies to reduce the amount of infiltration into the building. These methods will help improve indoor air quality, but by themselves they cannot keep a building from becoming an unhealthy place to breathe. While proper building ventilation is a key component to improving indoor air quality, it cannot do the job on its own. As stated earlier, awareness is the key component to improving air quality, when choosing building materials, furnishings, and decorations. When architects and engineers implement best practices in ventilation and mechanical systems, the owner must maintain good air quality levels thereafter.

Limit Values for VOC Emissions

Limit values for VOC emissions into indoor air are published by e.g. AgBB, AFSSET, California Department of Public Health, and others.

Chemical Fingerprinting

The exhaled human breath contains a few hundred volatile organic compounds and is used in breath analysis to serve as a VOC biomarker to test for diseases such as lung cancer. One study has shown that "volatile organic compounds ... are mainly blood borne and therefore enable monitoring of different processes in the body." And it appears that VOC compounds in the body "may be either produced by metabolic processes or inhaled/absorbed from exogenous sources" such as environmental tobacco smoke. Research is still in the process to determine whether VOCs in the body are contributed by cellular processes or by the cancerous tumors in the lung or other organs.

Volatile Organic Chemicals	MCL (ppb)	Potential Health Effects
Benzene	5	Cancer
Carbon tetrachloride	5	Liver effects, cancer
Chlorobenzene	100	Liver, kidney, nervous system effects
o-Dichlorobenzene	600	Liver, kidney, blood cell effects
para-Dichlorobenzene	175	Kidney effects, possible carcinogen
1,2-Dichloroethane	5	Cancer
1,1-Dichloroethylene	7	Liver, kidney effects, possible carcinogen
cis-1,2-Dichloroethylene	70	Liver, kidney, nervous system, circulatory system effects
trans-1,2-Dichloroethylene	100	Liver, kidney, nervous system, circulatory system effects
1,2-Dichloropropane	5	Cancer
Ethylbenzene	700	Liver, kidney, nervous system effects
Methylene chloride	5	Cancer
Styrene	100	Liver, nervous systems effects, possible carcinogen
Tetrachloroethylene (PCE)	5	Cancer
Toluene	1,000	Liver, kidney, nervous system, circulatory system effects
Total trihalomethanes Chloroform Bromoform Bromodichloromethane Chlorodibromomethane	100	Cancer
1,2,4-Trichlorobenzene	70	Liver, kidney effects
1,1,1-Trichloroethane	200	Liver, nervous system effects
1,1,2-Trichloroethane	5	Kidney, liver effects, possible carcinogen
Trichloroethylene (TCE)	5	Cancer
Vinyl chloride	2	Nervous system, liver effects, cancer
Xylenes (total)	10,000	Liver, kidney, nervous system effects

Disinfection By-products	MCL (ppb)	Potential Health Effects
Bromate	10	Cancer
Chlorate	1,000	Anemia, nervous system effects
Haloacetic Acids (HAA5)*	60	Cancer
Total trihalomethanes (TTHMs)**	100	Cancer

*Haloacetic acids consist of monochloroacetic acid, dichloroacetic acid, trichloroacetic acid, monobromoacetic acid, and dibromoacetic acid.

**Total trihalomethanes consist of chloroform, bromoform, bromodichloromethane, and chlorodibromomethane.

Periodic Table of the Elements

1 IA New Original Alkali metals Alkaline earth metals Transition metals Lanthanide series Actinide series Poor metals Nonmetals Noble gases C Solid Br Liquid H Gas Tc Synthetic																	
1	2											13	14	15	16	17	18
1 H	2 He											B	C	N	O	F	Ne
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg	3	4	5	6	7	8	9	10	11	12	13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57 to 71	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89 to 103	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Uub	113 Uut	114 Uuq	115 Uup	116 Uuh	117 Uus	118 Uuo

Atomic masses in parentheses are those of the most stable or common isotope.

57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

Note: The subgroup numbers 1-18 were adopted in 1984 by the International Union of Pure and Applied Chemistry. The names of elements 112-118 are the Latin equivalents of those numbers.



Germanium, left and Boron, right

Metalloid Section

Drinking water contaminants that can cause health effects after continuous long-term exposure at levels greater than the maximum contaminant level (MCL) are considered “chronic” contaminants. Examples of chronic drinking water contaminants regulated by EPA include inorganic contaminants like arsenic, cadmium, and copper; organic contaminants such as pesticides and industrial chemicals; and radiological contaminants like radium and uranium.

If your water system has installed some form of inorganic contaminant or arsenic treatment, keep in mind that the treatment you installed may change the water quality in other ways. It might cause the water to react differently in the distribution system. Depending on the kind of treatment you’ve installed, consider what distribution system problems might result.

A change in the taste, odor or appearance of the water at customers’ taps may be the first indication of a problem. Some water quality parameters to consider monitoring, depending on your arsenic treatment technology, include iron, pH, manganese, alkalinity, and aluminum.

In contrast, “acute” contaminants can cause short-term health effects within hours or days of exposure. Microbes such as *E. coli* and *Cryptosporidium* are examples of contaminants that can cause an acute health risk. Some chronic-type contaminants can also fall in this category if they are present at high enough concentrations to cause immediate health effects. For example, nitrate levels over the MCL can cause “blue-baby” syndrome in children less than 6 months.

Arsenic, boron, silicon, germanium, antimony and tellurium are commonly classified as metalloids. One or more from among selenium, polonium or astatine are sometimes added to the list. Boron is sometimes excluded from the list, by itself or together with silicon. Tellurium is sometimes not regarded as a metalloid. The inclusion of antimony, polonium and astatine as metalloids has also been questioned.

A metalloid is a chemical element with properties that are in-between or a mixture of those of metals and nonmetals, and which is considered to be difficult to classify unambiguously as either a metal or a nonmetal. There is no standard definition of a metalloid nor is there agreement as to which elements are appropriately classified as such. Despite this lack of specificity the term continues to be used in the chemistry literature.

Some authors do not classify elements bordering the metal-nonmetal dividing line as metalloids noting that a binary classification can facilitate the establishment of some simple rules for determining bond types between metals and/or nonmetals. Other authors, in contrast, have suggested that classifying some elements as metalloids 'emphasizes that properties change gradually rather than abruptly as one moves across or down the periodic table. Alternatively, some periodic tables distinguish elements that are metalloids in the absence of any formal dividing line between metals and nonmetals. Metalloids are instead shown as occurring in a diagonal fixed band or diffuse region, running from upper left to lower right, centered around arsenic.

The six elements commonly recognized as metalloids are boron, silicon, germanium, arsenic, antimony and tellurium. They are metallic-looking brittle solids, with intermediate to relatively good electrical conductivities, and each having the electronic band structure of either a semiconductor or a semimetal.

Chemically, they mostly behave as (weak) nonmetals, have intermediate ionization energy and electronegativity values, and form amphoteric or weakly acidic oxides. Being too brittle to have any structural uses, the metalloids and their compounds instead find common use in glasses, alloys and semiconductors. The electrical properties of silicon and germanium, in particular, enabled the establishment of the semiconductor industry in the 1950s and the development of solid state electronics from the early 60s onwards.

Other elements less commonly recognized as metalloids include carbon, aluminum, selenium, polonium and astatine. On a standard periodic table these elements, as well as the elements commonly recognized as metalloids, occur in or near a diagonal region of the p-block, having its main axis anchored by boron at one end and astatine at the other. Some periodic tables include a dividing line between metals and nonmetals and it is generally the elements adjacent to this line or, less frequently, one or more of the elements adjacent to those elements, which are identified as metalloids.

The term *metalloid* was first popularly used to refer to nonmetals. It's more recent meaning as a category of elements with intermediate or hybrid properties did not become widespread until the period 1940–1960. Metalloids are sometimes called semimetals, a practice which has been discouraged. This is because the term *semimetal* has a different meaning in physics, one which more specifically refers to the electronic band structure of a substance rather than the overall classification of a chemical element.

There is no universally agreed or rigorous definition of a metalloid. The feasibility of establishing a specific definition has also been questioned, noting anomalies can be found in several such attempted constructs. Classifying any particular element as a metalloid has been described as 'arbitrary'.

The generic definition set out at the start of this article is based on metalloid attributes consistently cited in the literature. Illustrative definitions and extracts include:

- 'In chemistry a metalloid is an element with properties intermediate between those of metals and nonmetals.'
- 'Between the metals and nonmetals in the periodic table we find elements...[that] share some of the characteristic properties of both the metals and nonmetals, making it difficult to place them in either of these two main categories.'
- 'Chemists sometimes use the name metalloid...for these elements which are difficult to classify one way or the other.'
- 'Because the traits distinguishing metals and nonmetals are qualitative in nature, some elements do not fall unambiguously in either category. These elements...are called metalloids...'

More Broadly, Metalloids have also been referred to as:

- 'elements that...are somewhat of a cross between metals and nonmetals' or
- 'weird in-between elements.'

The criterion that metalloids are difficult to unambiguously classify one way or the other is a key tenet. In contrast, elements such as sodium and potassium 'have metallic properties to a high degree' and fluorine, chlorine and oxygen 'are almost exclusively nonmetallic.'

Although most other elements have a mixture of metallic and nonmetallic properties most such elements can also be classified as either metals or nonmetals according to which set of properties are regarded as being more pronounced in them. It is only the elements at or near the margins, ordinarily those that are regarded as lacking a sufficiently clear preponderance of metallic or nonmetallic properties, which are classified as metalloids.

Which Elements are Metalloids?

There is no universally agreed or rigorous definition of the term metalloid. So the answer to the question "Which elements are metalloids?" can vary, depending on the author and their inclusion criteria. Emsley, for example, recognized only four: germanium, arsenic, antimony and tellurium. James et al., on the other hand, listed twelve: boron, carbon, silicon, germanium, arsenic, selenium, antimony, tellurium, bismuth, polonium, ununpentium and livermorium. As of 2011 the list of metalloid lists recorded an average of just over seven elements classified as metalloids, per list of metalloids, based on a sample size of 194 lists.

The absence of a standardized division of the elements into metals, metalloids and nonmetals is not necessarily an issue. There is a more or less continuous progression from the metallic to the nonmetallic. A specified subset of this continuum can potentially serve its particular purpose as well as any other. In any event, individual metalloid classification arrangements tend to share common ground (as described above) with most variations occurring around the indistinct margins, as surveyed later.

How Are Chronic Contaminants Regulated?

In 1974, Congress passed the Safe Drinking Water Act (SDWA) to give EPA the authority to set standards to ensure the safety of drinking water provided by public water systems. The SDWA, which was amended in 1986 and 1996, directs EPA to establish non-enforceable health goals called maximum contaminant level goals (MCLGs) which reflect the level at which no adverse health effects are expected from a particular contaminant.

Once an MCLG is established, EPA sets enforceable standards for contaminants called maximum contaminant levels (MCLs). MCLs are set as close to the health goals as possible considering cost, benefits, and the ability of public water systems to detect and remove contaminants using appropriate treatment technologies. When there is no reliable method to measure a contaminant that is economically and technically feasible, EPA develops a treatment technique requirement rather than an MCL. EPA continues to assess the occurrence of unregulated contaminants through the Unregulated Contaminant Monitoring Regulation (UCMR). Information about the UCMR can be found at <http://www.epa.gov/safewater/ucmr/>.

What Are Some Best Practices For Effective Communication About Chronic Contaminants?

If you expect that your public water system will exceed EPA's standard for a contaminant or that the costs of compliance may require public funding, communicate early and often. The most effective communication efforts follow these simple steps:

- Provide simple, straightforward, *and consistent* messages;
- Describe potential adverse health effects and populations at risk;
- Describe actions you are taking to correct the situation and when you anticipate it will be resolved;
- Describe actions the consumer can take such as using alternate water supplies and when to seek medical help;
- Provide links to useful information resources such as EPA's Web site.
- Use graphics, photographs, maps, charts, and drawings to illustrate your messages;
- Assume that consumers will only read the top half of the notice or what can be read in ten seconds;
- Display important elements in bold and/or large type in the top half of the notice;
- Communicate in multiple languages to meet the needs of your non-English speaking consumers; and Include contact information for further information in *all* communications.

Near Metalloids

The concept of a class of elements intermediate between metals and nonmetals is sometimes extended to include elements that most chemists, and related science professionals, would not ordinarily recognize as metalloids. In 1935, Fernelius and Robey allocated carbon, phosphorus, selenium, and iodine to such an intermediary class of elements, together with boron, silicon, arsenic, antimony, tellurium and polonium. They also included a placeholder for the missing element 85 (astatine), five years ahead of its synthesis in 1940.

They excluded germanium from their considerations as it was still then regarded as a poorly conducting metal. In 1954, Szabó & Lakatos counted beryllium and aluminum in their list of metalloids, as well as boron, silicon, germanium, arsenic, antimony, tellurium, polonium and astatine. In 1957, Sanderson recognized carbon, phosphorus, selenium, and iodine as part of an intermediary class of elements with 'certain metallic properties', together with boron, silicon, arsenic, tellurium, and astatine. Germanium, antimony and polonium were classified by him as metals. More recently, in 2007, Petty included carbon, phosphorus, selenium, tin and bismuth in his list of metalloids, as well as boron, silicon, germanium, arsenic, antimony, tellurium, polonium and astatine.

Elements such as these are occasionally called, or described as, *near-metalloids*, or the like. They are located near the elements commonly recognized as metalloids, and usually classified as either metals or nonmetals. Metals falling into this loose category tend to show 'odd' packing structures, marked covalent chemistry (molecular or polymeric), and amphoterism. Aluminum, tin and bismuth are examples. They are also referred to as (*chemically*) *weak metals*, *poor metals*, *post-transition metals*, or *semimetals* (in the aforementioned sense of metals with incomplete metallic character). These classification groupings generally cohabit the same periodic table territory but are not necessarily mutually inclusive.

Nonmetals in the 'near-metalloid' category include carbon, phosphorus, selenium and iodine. They exhibit metallic luster, semiconducting properties and bonding or valence bands with delocalized character. This applies to their most thermodynamically stable forms under ambient conditions: carbon as graphite; phosphorus as black phosphorus; and selenium as grey selenium. These elements are alternatively described as being 'near metalloid', showing metalloid character, or having metalloid-like or some metalloid(al) or metallic properties.

Allotropes

Some allotropes of the elements exhibit more pronounced metallic, metalloid or nonmetallic behavior than others. For example, the diamond allotrope of carbon is clearly nonmetallic. The graphite allotrope however displays limited electrical conductivity more characteristic of a metalloid. Phosphorus, selenium, tin, and bismuth also have allotropes that display borderline or either metallic or nonmetallic behavior.

Categorization and Periodic Table Territory

Metalloids are generally regarded as a third category of chemical elements, alongside metals and nonmetals. They have been described as forming a (fuzzy) buffer zone between metals and nonmetals. The make-up and size of this zone depends on the classification criteria being used. Metalloids are sometimes grouped instead with metals, regarded as nonmetals or treated as a sub-category of same.

Metalloid Border

H								He
Li	Be		B	C	N	O	F	Ne
Na	Mg		Al	Si	P	S	Cl	Ar
K	Ca	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Cn	Uut	Fl	Uup	Lv	Uus	Uuo

Periodic table extract showing elements that have sometimes¹ been classified as metalloids:

Elements that appear commonly to rarely in the list of metalloid lists.

Elements that appear still less frequently.

Outlying elements showing that the metalloid net is sometimes cast very widely. Although they do not appear in the list of metalloids lists, isolated references to their designation as metalloids can be found in the literature.

Metalloids cluster on either side of the **dividing line between metals and nonmetals**. This can be found, in varying configurations, on some periodic tables (see mini-example, right). Elements to the lower left of the line generally display increasing metallic behavior; elements to the upper right display increasing nonmetallic behavior. When presented as a regular stair-step, elements with the highest critical temperature for their groups (Li, Be, Al, Ge, Sb, Po) lie just below the line.

The diagonal positioning of the metalloids represents somewhat of an exception to the phenomenon that elements with similar properties tend to occur in vertical columns. Going across a periodic table row, the nuclear charge increases with atomic number just as there is as a corresponding increase in electrons. The additional 'pull' on outer electrons with increasing nuclear charge generally outweighs the screening efficacy of having more electrons. With some irregularities, atoms therefore become smaller, ionization energy increases, and there is a gradual change in character, across a period, from strongly metallic, to weakly metallic, to weakly nonmetallic, to strongly nonmetallic elements.

Going down a main group periodic table column, the effect of increasing nuclear charge is generally outweighed by the effect of additional electrons being further away from the nucleus. With some irregularities, atoms therefore become larger, ionization energy falls, and metallic character increases. The combined effect of these competing horizontal and vertical trends is that the location of the metal-nonmetal transition zone shifts to the right in going down a period.

A related effect can be seen in other diagonal similarities that occur between some elements and their lower right neighbors, such as lithium-magnesium, beryllium-aluminum, carbon-phosphorus, and nitrogen-sulfur.

Other Metalloids

Given there is no agreed definition of a metalloid, some other elements are occasionally classified as such. These elements include hydrogen, beryllium, nitrogen, phosphorus, sulfur, zinc, gallium, tin, iodine, lead, bismuth and radon. The term metalloid has also been used to refer to:

- Elements that exhibit metallic luster and electrical conductivity, and that are also amphoteric. Arsenic, antimony, vanadium, chromium, molybdenum, tungsten, tin, lead and aluminum are examples.
- Elements that are otherwise sometimes referred to as poor metals.
- Nonmetallic elements (for example, nitrogen; carbon) that can form alloys with, or modify the properties of, metals.

Heavy Metals

A heavy metal is a member of a loosely defined subset of elements that exhibit metallic properties. It mainly includes the transition metals, some metalloids, lanthanides, and actinides. Many different definitions have been proposed—some based on density, some on atomic number or atomic weight, and some on chemical properties or toxicity. The term *heavy metal* has been called a "misinterpretation" in an IUPAC technical report due to the contradictory definitions and its lack of a "coherent scientific basis". There is an alternative term *toxic metal*, for which no consensus of exact definition exists either. As discussed below, depending on context, heavy metal can include elements lighter than carbon and can exclude some of the heaviest metals. Heavy metals occur naturally in the ecosystem with large variations in concentration. In modern times, anthropogenic sources of heavy metals, i.e. pollution, have been introduced to the ecosystem. Waste-derived fuels are especially prone to contain heavy metals, so heavy metals are a concern in consideration of waste as fuel.

Motivations for controlling heavy metal concentrations in gas streams are diverse. Some of them are dangerous to health or to the environment (e.g. mercury, cadmium, lead, chromium), some may cause corrosion (e.g. zinc, lead), some are harmful in other ways (e.g. arsenic may pollute catalysts). Within the European community the eleven elements of highest concern are arsenic, cadmium, cobalt, chromium, copper, mercury, manganese, nickel, lead, tin, and thallium, the emissions of which are regulated in waste incinerators. Some of these elements are actually necessary for humans in minute amounts (cobalt, copper, chromium, manganese, nickel) while others are carcinogenic or toxic, affecting, among others, the central nervous system (manganese, mercury, lead, arsenic), the kidneys or liver (mercury, lead, cadmium, copper) or skin, bones, or teeth (nickel, cadmium, copper, chromium).

Heavy metal pollution can arise from many sources but most commonly arises from the purification of metals, e.g., the smelting of copper and the preparation of nuclear fuels. Electroplating is the primary source of chromium and cadmium. Through precipitation of their compounds or by ion exchange into soils and muds, heavy metal pollutants can localize and lay dormant. Unlike organic pollutants, heavy metals do not decay and thus pose a different kind of challenge for remediation. Currently, plants or microorganisms are tentatively used to remove some heavy metals such as mercury.

Plants which exhibit hyper accumulation can be used to remove heavy metals from soils by concentrating them in their bio matter. Some treatment of mining tailings has occurred where the vegetation is then incinerated to recover the heavy metals.

One of the largest problems associated with the persistence of heavy metals is the potential for bioaccumulation and biomagnification causing heavier exposure for some organisms than is present in the environment alone. Coastal fish (such as the smooth toadfish) and seabirds (such as the Atlantic Puffin) are often monitored for the presence of such contaminants.

Living organisms require varying amounts of "heavy metals". Iron, cobalt, copper, manganese, molybdenum, and zinc are required by humans. Excessive levels can be damaging to the organism. Other heavy metals such as mercury, plutonium, and lead are toxic metals that have no known vital or beneficial effect on organisms, and their accumulation over time in the bodies of animals can cause serious illness. Certain elements that are normally toxic are, for certain organisms or under certain conditions, beneficial. Examples include vanadium, tungsten, and even cadmium.

Toxic Metals

Toxic metals are metals that form poisonous soluble compounds and have no biological role, i.e. are not essential minerals, or are in the wrong form. Often heavy metals are thought as synonymous, but lighter metals also have toxicity, such as beryllium, and not all heavy metals are particularly toxic, and some are essential, such as iron. The definition may also include trace elements when considered in abnormally high, toxic doses. A difference is that there is no beneficial dose for a toxic metal with no biological role.

Toxic metals sometimes imitate the action of an essential element in the body, interfering with the metabolic process to cause illness. Many metals, particularly heavy metals are toxic, but some heavy metals are essential, and some, such as bismuth, have a low toxicity. Most often the definition includes at least cadmium, lead, mercury and the radioactive metals. Metalloids (arsenic, polonium) may be included in the definition.

Radioactive metals have both radiological toxicity and chemical toxicity. Metals in an oxidation state abnormal to the body may also become toxic: chromium (III) is an essential trace element, but chromium (VI) is a carcinogen.

Toxicity is a function of solubility. Insoluble compounds as well as the metallic forms often exhibit negligible toxicity. The toxicity of any metal depends on its ligands. In some cases, organometallic forms, such as dimethyl mercury and tetraethyl lead, can be extremely toxic. In other cases, organometallic derivatives are less toxic such as the cobaltocenium cation.

Decontamination for toxic metals is different from organic toxins: because toxic metals are elements, they cannot be destroyed. Toxic metals may be made insoluble or collected, possibly by the aid of chelating agents. Toxic metals can bioaccumulate in the body and in the food chain. Therefore, a common characteristic of toxic metals is the chronic nature of their toxicity. This is particularly notable with radioactive heavy metals such as thorium, which imitates calcium to the point of being incorporated into human bone, although similar health implications are found in lead or mercury poisoning. The exceptions to this are barium and aluminum, which can be removed efficiently by the kidneys.

Toxic Heavy Metals

- Antimony (a metalloid)
- Arsenic is a metalloid
- Barium
- Beryllium
- Cadmium - cadmium poisoning
- Lead - lead poisoning
- Mercury - mercury poisoning
- Osmium
- Thallium
- Vanadium
- Radioactive metals:
 - o Actinium
 - o Thorium
 - o Uranium
 - o Radium
 - o The transuraniums, such as plutonium, americium, etc.
 - o Polonium
 - o Radioactive isotopes of metallic elements not otherwise strongly toxic, e.g. cobalt-60 and strontium-90.

Aluminum has no biological role and its classification into toxic metals is controversial. Significant toxic effects and accumulation to tissues have been observed in renally impaired patients. However, individuals with healthy kidneys can be exposed to large amounts of aluminum with no ill effects. Thus, aluminum is not considered dangerous to persons with normal elimination capacity.

Trace Elements with Toxicity

- Chromium as hexavalent Cr(VI)
- Nickel – nickel salts are carcinogenic
- Copper – copper toxicity
- Zinc - zinc toxicity
- Iron – iron poisoning
- Fluorine-fluoride poisoning

Nonmetals

Some heavy nonmetals may be erroneously called "metals", because they have some metallic properties.

- Selenium – a nonmetal; essential element
- Tellurium

Atomic Spectrometry

Atomic spectrometry converts each metal in the water sample to a particulate emission that can then be weighed. Extrapolations are made to determine each metal concentration in each water sample taken. The complicated analysis requires preserving the sample with acid, heating the sample to convert to a particulate emission and then identifying each metal and its weight.

A simple analogy is to capture the steam from a pot of water, separate every atom in the steam, identify each atom, weigh each atom and then apply these numbers back to the original volume of water contained in the pot. The result is an accurate picture of what is in the water.

Heavy Metals in Water

High heavy metals concentrations can be naturally occurring. Every geologic formation contains a certain amount of heavy metal. Mine operations extract and process these metals in areas with the highest concentrations. Water in these areas may have high metal concentrations due to the combination of naturally occurring deposits and mine waste. Water samples are usually taken randomly within a contaminated area and offsite to identify the source of contamination and the pathway it travels, into the drinkable groundwater system or away from potable water sources. Accurate determination of heavy metal contamination is important to identify cumulative risks to people drinking water derived from these areas.

Treating Heavy Metal Contamination in Water

Heavy metal water contamination is a difficult expensive problem to address. Most cleanup activities use a pump and treat system where contaminated groundwater is pumped out of the ground, treated with activated carbon to remove contaminants and then replaced into the groundwater system. Because large volumes of water must be pumped and treated over long time periods, associated operation and maintenance systems are very expensive. There are some new technologies being developed that actually treat the water in the ground which operate more efficiently and quickly, decreasing costs.

If groundwater is contaminated with heavy metals, an alternative source of drinking water must be used to prevent harmful health effects, until the water is treated to meet standards protective of human health and the environment

Health Significance of Metals in the Environment

The metallic elements can be categorized into two groups. The heavy metals are those having densities five times greater than water, and the light metals, those having lesser densities. Well-known examples of heavy metallic elements are iron, lead, and copper. Examples of light metals are sodium, magnesium, and potassium. Humans consume metallic elements through both water and food. Some metals such as sodium, potassium, magnesium, calcium, and iron are found in living tissue and are essential to human life-biological anomalies arise when they are depleted or removed. Probably less well known is that currently no less than six other heavy metals including molybdenum, manganese, cobalt, copper, and zinc, have been linked to human growth, development, achievement, and reproduction (Vahrenkamp, 1979; Friberg and others, 1979). Even these metals, however, can become toxic or aesthetically undesirable when their concentrations are too great. Several heavy metals, like cadmium, lead, and mercury, are highly toxic at relatively low concentrations, can accumulate in body tissues over long periods of time, and are nonessential for human health. Table 1 lists metals according to their toxicities.

No specific health guidelines for heavy metals associated with suspended or bed sediments have been established by the U.S. Environmental Protection Agency. This lack of national guidelines based on concise scientific criteria causes difficulty when evaluating the environmental effects of heavy metals in sediments. Several different criteria have been defined, primarily on the basis of observed effects on aquatic life (Lyman and others, 1987). Table 2 lists criteria for open-water disposal of polluted sediments that can be used for comparison purposes.

Table 1. Classification of naturally occurring metals according to their toxicity and availability in the hydrologic environment (from Wood, 1974)

[Metals that normally do not exist as dissolved species in natural waters or are very rare in crustal rocks are in italics]

Nontoxic		Low toxicity		Moderate to high toxicity			
Aluminum	Magnesium	Barium	<i>Praseodymium</i>	<i>Actinium</i>	Indium	Polonium	Uranium
Bismuth	Manganese	<i>Cerium</i>	<i>Promethium</i>	Antimony	<i>Iridium</i>	<i>Radium</i>	Vanadium
Calcium	Molybdenum	<i>Dysprosium</i>	<i>Rhenium</i>	Beryllium	Lead	<i>Ruthenium</i>	Zinc
Cesium	Potassium	<i>Erbium</i>	<i>Rhodium</i>	Boron	Mercury	Silver	<i>Zirconium</i>
Iron	Strontium	<i>Europium</i>	<i>Samarium</i>	Cadmium	Nickel	<i>Tantalum</i>	
Lithium	Rubidium	<i>Gadolinium</i>	Scandium	Chromium	<i>Niobium</i>	Thallium	
	Sodium	<i>Gallium</i>	<i>Terbium</i>	Cobalt	<i>Osmium</i>	Thorium	
		Germanium	Thulium	Copper	Palladium	<i>Titanium</i>	
		<i>Gold</i>	<i>Tin</i>	<i>Hafnium</i>	Platinum	<i>Tungsten</i>	
		<i>Holmium</i>	<i>Ytterbium</i>				
		<i>Neodymium</i>	Yttrium				

Table 2. U.S. Environmental Protection Agency maximum contaminant levels for heavy-metal concentrations in drinking water and water supporting aquatic life, and criteria for open-water disposal of polluted sediments

[µg/L, microgram per liter; µg/g, microgram per gram; >, greater than; <, less than; --, no guideline available]

	Cadmium	Chromium	Copper	Lead	Mercury	Uranium
Drinking water, in µg/L ¹	5	100	² 1,000	15	2	³ 20
Water supporting aquatic life, in µg/L ⁴	12	100	20	100	0.05	—
Natural sediments, nonpolluted, in µg/g ⁵	--	<25	<25	<40	<1	—
Natural sediments, moderately polluted, in µg/g ⁵	--	25 to 75	25 to 50	40 to 60	--	—
Natural sediments, heavily polluted, in µg/g ⁵	>6	>75	>50	>60	>1	—

¹U.S. Environmental Protection Agency, 1992.

²Secondary maximum contaminant level based on esthetic water quality.

³Proposed maximum contaminant level.

⁴U.S. Environmental Protection Agency, 1982.

⁵Great Lakes Water Quality Board, Dredging Subcommittee, 1982.

Antimony - Inorganic Contaminant 0.006 mg/L MCL

Metalloid See Antimony in IOC Section for more information

Antimony is a toxic chemical element with symbol **Sb** and atomic number 51. A lustrous gray metalloid, it is found in nature mainly as the sulfide mineral stibnite (Sb_2S_3). Antimony compounds have been known since ancient times and were used for cosmetics; metallic antimony was also known, but it was erroneously identified as lead. It was established to be an element around the 17th century.

For some time, China has been the largest producer of antimony and its compounds, with most production coming from the Xikuangshan Mine in Hunan. The industrial methods to produce antimony are roasting and subsequent carbothermal reduction or direct reduction of stibnite with iron.

What are EPA's drinking water regulations for antimony?

In 1974, Congress passed the Safe Drinking Water Act. This law requires EPA to determine the level of contaminants in drinking water at which no adverse health effects are likely to occur. These non-enforceable health goals, based solely on possible health risks and exposure over a lifetime with an adequate margin of safety, are called maximum contaminant level goals (MCLG). Contaminants are any physical, chemical, biological or radiological substances or matter in water.



The MCLG for antimony is 0.006 mg/L or 6 ppb. EPA has set this level of protection based on the best available science to prevent potential health problems. EPA has set an enforceable regulation for antimony, called a maximum contaminant level (MCL), at 0.006 mg/L or 6 ppb. MCLs are set as close to the health goals as possible, considering cost, benefits and the ability of public water systems to detect and remove contaminants using suitable treatment technologies. In this case, the MCL equals the MCLG, because analytical methods or treatment technology do not pose any limitation.

The Phase V Rule, the regulation for antimony, became effective in 1994. The Safe Drinking Water Act requires EPA to periodically review the national primary drinking water regulation for each contaminant and revise the regulation, if appropriate. EPA reviewed antimony as part of the Six Year Review and determined that the 0.006 mg/L or 6 ppb MCLG and 0.006 mg/L or 6 ppb MCL for antimony are still protective of human health.

Applications

The largest applications for metallic antimony are as alloying material for lead and tin and for lead antimony plates in lead-acid batteries. Alloying lead and tin with antimony improves the properties of the alloys which are used in solders, bullets and plain bearings. Antimony compounds are prominent additives for chlorine- and bromine-containing fire retardants found in many commercial and domestic products. An emerging application is the use of antimony in microelectronics.

Antimony is in the nitrogen group (group 15) and has an electronegativity of 2.05. As expected by periodic trends, it is more electronegative than tin or bismuth, and less electronegative than tellurium or arsenic. Antimony is stable in air at room temperature, but reacts with oxygen if heated to form antimony trioxide, Sb_2O_3 . Antimony is a silvery, lustrous gray metal that has a Mohs scale hardness of 3. Therefore, pure antimony is not used to make hard objects: coins made of antimony were issued in China's Guizhou province in 1931, but because of their rapid wear, their minting was discontinued. Antimony is resistant to attack by acids.

Four allotropes of antimony are known, a stable metallic form and three metastable forms, explosive, black and yellow. Metallic antimony is a brittle, silver-white shiny metal. When molten antimony is slowly cooled, metallic antimony crystallizes in a trigonal cell, isomorphic with that of the gray allotrope of arsenic. A rare explosive form of antimony can be formed from the electrolysis of antimony (III) trichloride. When scratched with a sharp implement, an exothermic reaction occurs and white fumes are given off as metallic antimony is formed; when rubbed with a pestle in a mortar, a strong detonation occurs.

Black antimony is formed upon rapid cooling of vapor derived from metallic antimony. It has the same crystal structure as red phosphorus and black arsenic; it oxidizes in air and may ignite spontaneously. At 100 °C, it gradually transforms into the stable form. The yellow allotrope of antimony is the most unstable. It has only been generated by oxidation of stibine (SbH_3) at -90 °C. Above this temperature and in ambient light, this metastable allotrope transforms into the more stable black allotrope.

Metallic antimony adopts a layered structure (space group $R\bar{3}m$ No. 166) in which layers consist of fused ruffled six-membered rings. The nearest and next-nearest neighbors form a distorted octahedral complex, with the three atoms in the same double-layer being slightly closer than the three atoms in the next. This relatively close packing leads to a high density of 6.697 g/cm^3 , but the weak bonding between the layers leads to the low hardness and brittleness of antimony.

Isotopes

Antimony exists as two stable isotopes, ^{121}Sb with a natural abundance of 57.36% and ^{123}Sb with a natural abundance of 42.64%. It also has 35 radioisotopes, of which the longest-lived is ^{125}Sb with a half-life of 2.75 years. In addition, 29 metastable states have been characterized. The most stable of these is ^{124}Sb with a half-life of 60.20 days, which has an application in some neutron sources. Isotopes that are lighter than the stable ^{123}Sb tend to decay by β^+ decay, and those that are heavier tend to decay by β^- decay, with some exceptions.

Occurrence

The abundance of antimony in the Earth's crust is estimated at 0.2 to 0.5 parts per million, comparable to thallium at 0.5 parts per million and silver at 0.07 ppm. Even though this element is not abundant, it is found in over 100 mineral species. Antimony is sometimes found natively, but more frequently it is found in the sulfide stibnite (Sb_2S_3) which is the predominant ore mineral.

Astatine- Nonmetal or a Metalloid

Astatine may be a nonmetal or a metalloid. It is ordinarily classified as a nonmetal, but has some 'marked' metallic properties. Immediately following its production in 1940, early investigators considered it to be a metal. In 1949 it was called the most noble (difficult to reduce) nonmetal as well as being a relatively noble (difficult to oxidize) metal. In 1950 astatine was described as a halogen and (therefore) a reactive nonmetal.

In terms of metallic indicators:

- Samsonov observes that, '[L]ike typical metals, it is precipitated by hydrogen sulfide even from strongly acid solutions and is displaced in a free form from sulfate solutions; it is deposited on the cathode on electrolysis'.
- Rossler cites further indications of a tendency for astatine to behave like a (heavy) metal as: '...the formation of pseudohalide compounds...complexes of astatine cations...complex anions of trivalent astatine...as well as complexes with a variety of organic solvents'.
- Rao and Ganguly note that elements with an enthalpy of vaporization (EoV) greater than ~42 kJ/mol are metallic when liquid. Such elements include boron, silicon, germanium, antimony, selenium and tellurium. Vásáros & Berei give estimated values for the EoV of diatomic astatine, the lowest of these being 50 kJ/mol. On this basis astatine may also be metallic in the liquid state. Diatomic iodine, with an EoV of 41.71, falls just short of the threshold figure.
- Siekierski and Burgess contend or presume that astatine would be a metal if it could form a condensed phase.
- Champion et al. argue that astatine demonstrates cationic behavior, by way of stable At^+ and AtO^+ forms, in strongly acidic aqueous solutions.



For Nonmetallic Indicators:

- Batsanov gives a calculated band gap energy for astatine of 0.7 eV. This is consistent with nonmetals (in physics) having separated valence and conduction bands and thereby being either semiconductors or insulators.
- It has the narrow liquid range ordinarily associated with nonmetals (mp 575 K, bp 610).
- Its chemistry in aqueous solution is predominately characterized by the formation of various anionic species.
- Most of its known compounds resemble those of iodine, which is halogen and a nonmetal. Such compounds include astatides (XAt), astatates (XAtO_3), and monovalent interhalogen compounds.

Restrepo et al. reported that astatine appeared to share more in common with polonium than it did with the established halogens. They did so on the basis of detailed comparative studies of the known and interpolated properties of 72 elements.

Chapter 3

POTW Pretreatment Program Responsibilities

This Chapter provides an overview of these POTW programs, highlighting each of the specific program areas that are to be addressed.

Legal Authority

POTWs seeking pretreatment program approval must develop policy and procedures for program implementation and establish the legal authority to implement and enforce program requirements. The General Pretreatment Regulations do not provide Control Authorities with the legal authority to carry out their pretreatment programs; rather, the regulations set forth the minimum requirements for POTWs with pretreatment programs.

A Control Authority's legal authority actually derives from State law. Therefore, State law must confer the minimum Federal legal authority requirements on a Control Authority. Where deficient, State law must be modified to grant the minimum requirements. In order to apply regulatory authority provided by State law, it is generally necessary for the Control Authority to establish local regulations to legally implement and enforce pretreatment requirements. Where the Control Authority is a municipality, legal authority is detailed in a Sewer Use Ordinance (SUO), which is usually part of city or county code.

Regional Control Authorities frequently adopt similar provisions in the form of “**rules and regulations**.” Likewise, State agencies implementing a Statewide program under 40 CFR §403.10(e) set out pretreatment requirements as State regulations, rather than as an SUO. **[Local regulations cannot give the Control Authority greater authority than that provided by State law.]**

The EPA's 1992 guidance, *EPA Model Pretreatment Ordinance* provides a model for POTWs that are required to develop pretreatment programs. As POTW service areas expand, new contributions may arise from “**extra jurisdictional**” IUs located outside of the Control Authority's legal jurisdiction (see Figure 22). Multijurisdictional arrangements require special legal/contractual mechanisms to ensure adequate authority to implement and enforce program requirements in these other jurisdictions. Some state statutes may provide for general extraterritorial powers (i.e., a Control Authority is automatically allowed to regulate extra jurisdictional IUs contributing to their system).

However, the extent to which authorities (i.e., to permit, inspect, enforce, monitor, etc.) are granted may be somewhat limited, thereby, restricting a Control Authority's ability to implement and enforce a program. Where obtaining authority from the State to regulate extra jurisdictional IUs is not feasible, other options may be pursued:

Districts The creation of an independent organization (by affected municipalities or the State) which is authorized to administer and enforce an approved pretreatment program for the entire area in which it provides services is common in areas where multiple POTWs each serve various jurisdictions.

Agreements Affected Control Authorities may opt to enter into agreements requiring each municipality to implement and enforce the approved pretreatment program covering all IUs within their jurisdiction. The Control Authority must retain the means to regulate extra jurisdictional IUs where the contributing jurisdiction's efforts are inadequate. It is essential that agreements clearly define the roles of each party.

Annexation Where extra jurisdictional IUs lie in unincorporated areas, a Control Authority may annex or utility annex the service area.

Contracts

A Control Authority may enter into a contract with an extra jurisdictional IU, although contracts generally limit the enforcement capabilities of the Control Authority. As such, contracts should only be pursued when all other means fail. Since procedures for obtaining jurisdiction, creating sanitary districts, annexing service areas, etc. vary among states, Control Authority personnel should consult with their legal staff to thoroughly examine options allowed. This may include requesting State legislative changes if necessary.

The EPA's 1994 *Multijurisdictional Pretreatment Programs - Guidance Manual* provides more information on these jurisdictional issues, including sample language for agreements and contracts.

Industrial Waste Surveys

As part of program development and maintenance, the Federal regulations [40 CFR §403.8(f)(2)(I)] require Control Authorities to identify and locate all IUs that might be subject to the pretreatment program. While the General Pretreatment Regulations do not specify how a Control Authority is to accomplish this, it is beneficial to conduct an initial in-depth survey, and then institute measures to update the list continuously.

Control Authorities must ensure that the entire service area is reviewed. This may include IUs located outside the jurisdictional boundaries of the POTW. In these instances, it may be appropriate to solicit assistance from other jurisdictions in developing the list of potential dischargers. The types of resources that may be consulted in compiling and updating the master list include:

- Water and sewer billing records
- Applications for sewer service
- Local telephone directories
- Chamber of Commerce and local business directories
- Business license records
- POTW and wastewater collection personnel and field observations
- Business associations
- Internet

Once IUs are identified, the Control Authority must classify these users to determine if pretreatment standards and requirements should apply to these facilities. Typically, the Control Authority develops and distributes an Industrial Waste Survey (IWS) questionnaire to the identified IUs. The IWS questionnaire requests information regarding IU activities and the nature of wastes discharged.

The Control Authority may opt to send a detailed IWS questionnaire initially or conduct the survey in two phases (i.e., send a screener requesting basic information to eliminate obvious facilities and then send a detailed IWS to those facilities with greater potential to be SIUs). Key to the IWS is to identify facilities that are subject to categorical standards (i.e., CIUs) or otherwise have the potential to impact the POTW (i.e., SIUs). A POTW's IU inventory should include the name, location, classification, applicable standards, basis for limits imposed, and volume of discharge, control mechanism status, compliance dates and other special requirements for each IU.

The IWS should provide most of the information required to develop the inventory, although some supplementary information might be required from other sources, such as the permit application or monitoring data. The IU inventory must be updated as needed [40 CFR §403.8(f)(2)(I)] and provided to the Approval Authority as part of the annual report requirement (see POTW Reports section in this Chapter). The ongoing task of maintaining a complete list of IUs requires the Control Authority to implement a system to track existing IU information and/or classification changes and new user information. Some Control Authorities may proactively opt to institute a **"utility connect questionnaire"** program. These types of forms are completed when a customer applies for new utility service (e.g., water, sewerage, or electricity).

Permitting

The General Pretreatment Regulations require all IUs be controlled through permit, order, or similar means to ensure compliance with applicable pretreatment standards and requirements. Section 403.8(f)(1)(iii)(A-E) clarifies this requirement to specify that all SIUs be issued a permit or equivalent individual control mechanism which contains, at a minimum:

- Statement of duration (not to exceed five years);
- Statement of nontransferability (unless outlined provisions are met);
- Effluent limitations based on applicable standards;
- Self-monitoring, sampling, reporting, notification, and record-keeping requirements;
- Statement of applicable civil and criminal penalties; and a schedule of compliance (where appropriate).

The EPA's 1989 *Industrial User Permitting Guidance Manual* details procedures for drafting IU discharge permits. SIU permits issued are site specific and tailored to the unique circumstances of the IU. Permit conditions must establish clear and explicit requirements for the permittee, to include using such terms such as “**shall**” and “**must**” in lieu of vague terms such as “**recommend**” or “**may**”. The Control Authority must document its decision-making process when developing permits to ensure defensibility and enforceability. Adherence to sound, documented procedures will prevent any arbitrary and capricious claims by the permittee.

Whether developing or reissuing a permit, the permitting process consists of three phases:

Phase I - Collection and verification of information

Phase II - Data interpretation and fact sheet development

Phase III - Permit development and issuance.

Phase I

As part of Phase I, Control Authorities may review and verify information contained in the permit application, perform an inspection of the IU for confirmation of facts, tally data, and potentially sample and analyze the IU's wastestream. Knowledgeable Control Authority personnel, effective communication, and SIU cooperation are essential to collection of complete and accurate information.

Phase II requires that the Control Authority interpret data and other information and document the permit decision-making rationale, preferably in a permit fact sheet. Although the contents of a fact sheet will vary by permittee, fact sheets should provide a justification of all permitting decisions.

Typical components of a fact sheet are provided. Completed fact sheets should be included as part of the permit and provided to the Permittee to document the soundness of permitting decisions. For CIUs:

Components of Permit Fact Sheet

- the basis for the categorical determination(s)
- the identity and flow volume of all wastestreams generated and discharged to the POTW, and classified accordingly (i.e., regulated, unregulated, or dilution)
- data used and/or justification for estimates used to determine categorical limitations
- basis for limits imposed for categorical parameters.

For SIUs/CIUs:

- basis for limits imposed for non-categorical parameters
- rationale for compliance schedules, special plans required, special conditions, etc.
- basis for monitoring and reporting frequencies.

Inspection Considerations

- Provide current data on IUs
- Confirm or determine IUs' compliance status
- Determine completeness and accuracy of the IU's performance/compliance records
- Assess the adequacy of the IU's self-monitoring and reporting requirements
- Assess the adequacy of monitoring locations and IU's sampling techniques
- Assess the adequacy of imposed limitations and pollutants of concern
- Develop rapport with IUs
- Evaluate operation and maintenance and overall performance of an IU's pretreatment system
- Assess the potential for spills and slug loadings
- Evaluate the effectiveness of slug control plan
- Reveal issues requiring action
- Identify noncompliance needing resolution
- Suggest pollution prevention opportunities
- Collect samples
- Obtain data to support enforcement actions

After all permitting decisions are made; the Control Authority must incorporate those decisions into a permit. The permit, signed by the specified Control Authority official, is provided to the Permittee for comment and after comments are addressed, a final permit is issued to the IU. While many comments may be easily addressed/resolved by the Control Authority, occasionally resolution must be obtained through a formal adjudicatory hearing process where both the Permittee and Control Authority present their case to a third party.

Non-SIUs

Many POTWs also control contributions from non-SIUs using various means, such as through general permits issued to an entire industrial sector. These types of control mechanisms may not necessarily require compliance with specific pollutant limitations.

For example:

- ✓ Grease trap maintenance and record keeping requirements for food establishments;
- ✓ Maintenance and record-keeping requirements for photo processors' silver reclamation units;
- ✓ Best management practices for mercury recovery by hospitals and dentists.

Permit Application

All industrial users that require a permit must be sampled to determine the characteristics of the wastes to be discharged into the POTW's sewer system. Prior to the issuance of a permit for existing industrial users, the POTW's Inspector or Water Quality Department/Pollution Control Division samples the user's effluent, and performs the analyses required by the applicable discharge standards (i.e., Categorical standards or local limits).

For new industrial users, estimates of the wastes to be discharged into the POTW's sewer system must be submitted along with the permit application. No sampling would be performed at these new facilities, since they do not presently discharge wastes into the sewer system.

A four-day sampling program is usually conducted at each site to collect both composite and grab (for pollutants not amenable to composite sampling) samples as needed.

Industrial Sector

Industrial sector general permitting programs are common where a real or potential POTW problem is linked to a particular pollutant discharged (e.g., collection system blockages caused by the discharge of excess oils and grease from food establishments). POTWs have authority to enforce their SUO or rules or regulations against non-SIUs without the need for any type of individual control mechanism. Control Authorities have the authority to require non-SIUs to comply with pretreatment standards and requirements contained in their local regulations and then take appropriate actions against IUs as noncompliance is identified.

Inspections

Control Authorities are required to inspect and sample all SIUs a minimum of once per year pursuant to 40 CFR §403.8(f)(2)(v). The frequency with which a Control Authority actually inspects an SIU may vary depending on issues such as the variability of an SIU's effluent, the impact of their discharge on the POTW, and their compliance history.

Inspection considerations (see Figure 24) will hinge upon the type of inspection performed (i.e., scheduled, unscheduled or demand).

The EPA's 1994 *Industrial User Inspection and Sampling Manual for POTWs* provides a detailed reference for inspection procedures and protocols. Scheduled inspections are useful when the Control Authority wants to gather specific information from the facility that necessitates meeting with specific SIU contacts. However, since scheduled inspections may interrupt normal operations (e.g., altered production schedule as a result of preparative work undertaken by the IU), unscheduled inspections may more accurately reflect IU compliance status when the inspection is performed for that reason.

POTWs must evaluate, at least once every two years, whether each SIU needs a plan to control slug discharges (i.e., a discharge of a non-routine, episodic nature, including but not limited to an accidental spill or non-customary batch discharge). To accurately evaluate the slug potential, Control Authorities likely will have to examine the SIU during normal operating conditions. If undetected, slug discharges can have serious impacts on the POTW.

The EPA's 1991 *Control of Slug Loadings to POTWs Guidance Manual* provides a description of procedures for development, implementation, and review of slug control plans. Demand inspections are non-routine in nature and occur in response to a concern (e.g., POTW collection problems downstream from an IU, elevated enforcement actions against an IU, suspicious IU behavior, or an informer complaint).

Routine Control Authority inspections of SIUs typically consist of three activities; preparation, on-site assessment, and follow-up.

Preparation

Control Authority personnel should review POTW records for SIUs to be inspected to familiarize themselves with the facility. Information reviewed may include compliance status, compliance schedule activities, reports and plans, upcoming report and plan due dates, enforcement activities, permit applications, waste surveys, previous inspection summaries, categorical regulations, water use/billing records, and POTW collection system maps.

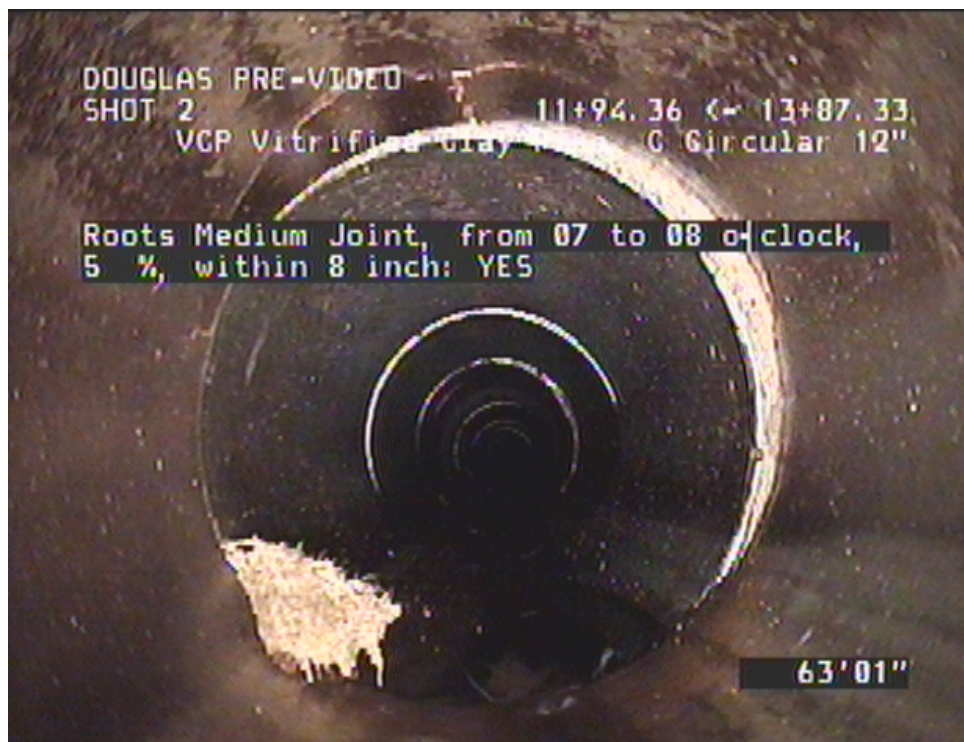
Control Authority personnel should also be familiar with any specific issues and concerns regarding the POTW treatment plant or collection system problems receiving the SIU's discharge.

On-site Assessment

Control Authority personnel typically discuss IU operations with IU contacts and perform a walkthrough of the facility to: update IU information regarding contacts, processes, production rates, pretreatment, and other waste management activities; review records required to be kept by the IU; visually verify the need for a slug control plan; and review pretreatment system maintenance, categorical standards applicable to processes employed, metering and sampling equipment, sampling procedures, chemicals used, processes employed, management practices, containment structures, locations of floor drains, etc. Many POTWs have developed a standard inspection questionnaire to facilitate the interview process and promote consistency during the inspection.

Follow-up

An inspection report should be prepared as soon as possible after the inspector returns to the office. Unanswered questions, required permit modifications, and/or necessary enforcement actions should be processed in a timely manner. Non-routine inspections (e.g., demand) may not encompass all the activities and steps specified above, but, like routine inspections, these activities may provide the Control Authority an opportunity to collect samples of the IU's discharge.



Sewer System Evaluation

On a regular basis, selected locations in the sewer system are sampled to develop background data for purposes of updating the local limits, and to screen areas for higher than "**background**" pollutant levels. In addition, problem areas are sampled on an as needed basis to determine potential sources of Code violations that either occur on a frequent basis, or are the result of a slug load to the sewer system.

To monitor sewers for background information, the sampling program would typically be conducted over a four-day period. In instances where the intent is to determine sources of pollutants and/or slug loads, the length of the program would vary.

Multi-City Users (Metering Stations) Example

All wastewater, which is transported to the POTW Treatment Plant from the Multi-City users, must be analyzed for pollutants of concern to the Industrial Pretreatment Program.

This type of sampling program is usually conducted over a seven-day period to obtain four-seven days of sampling data at each sewer location (i.e., a metering station) on a quarterly basis.

Once the sampling dates have been determined, the Inspector will notify, in writing, the Subregional Organizational Group (**SROG**) representative for that City of the dates when the sampling will be conducted.

Upon arrival at the site, safety is the priority. A visual inspection must be completed prior to any entry. The site must be free of any obstructions or hazards which may cause injury when entering the sampling area. If there are any problems detected, the SROG representative and the Inspector should be notified, and no entry should be attempted until the problem has been corrected.

Metering stations qualify as confined spaces (Example Policy)

If all safety criteria have been met, prepare equipment for the site. Check the assignment sheet to determine what parameters are required to be sampled, which in turn determines the type of tubing to be used (i.e. Tygon or Teflon).

The sampler must be completely assembled before performing QA/QC procedures. After QA/QC is complete, a sufficient amount of weight must be attached to the tubing to keep the strainer submerged in the effluent for proper siphoning of the sample, without allowing the strainer to hit the bottom of the flume. Make sure the intake tubing does not kink.

If the metering station has a flow meter, you may connect either their cable or a POTW cable to the sampler from the flow meter. Occasionally, you will set up a flow meter to have a comparison reading. Determine the pulse rate and proper setting from the flow, and program the sampler. After entering the data into the sampler, wait to make sure the equipment is pulling samples.

After the initial set-up of the sampling equipment, samples will be collected during the remainder of the sampling period. Split samples may be requested by the SROG representative. If the volume of the sample is adequate, these may be given, provided the representative supplies the containers and allows the City Inspector to pour off the samples.

**No grab samples will be collected by POTW Inspectors for any SROG representatives.
(Example Policy)**

Upon exiting the confined space, continue to follow the confined space entry procedures as outlined by OSHA Standards. When you return to the sampling vehicle, you must immediately perform field tests and preserve the samples according to the techniques set forth in by Standard Methods or the State/Federal Rule.

All paper work must be filled out completely before the sampling crew's departure. This paperwork includes the chain of custody which is turned in to the laboratory with the samples, "Metering Station Field Observation Form" that remains with the sampling site file, and the Multi-City Metering Station Sample Record, of which the original is given to the Inspector and the copy is given to the SROG representative.

If there is not an SROG representative at the site, these copies will be turned over to the Inspector with the originals at the end of the week. Remember, all paperwork must be completed prior to leaving the site.

Compliance Monitoring

There are two types of sampling activities that are performed as part of compliance monitoring for permitted industries: unscheduled and demand.

Unscheduled sampling is used to determine the compliance status of the user. Instances of noncompliance are often identified during unannounced monitoring visits. No notice is given for this type of sampling. This type of sampling is performed two to four times a year, at each industrial user site, over a two to five-day period to obtain sampling data

Demand sampling is usually initiated in response to a known or suspected violation, discovered as a result of a self-monitoring report, routine sampling visit, public complaint, unusual influent condition at the wastewater treatment plant, or emergency situations (e.g., plant upsets, sewer line blockages, fires, explosions, etc.). Most often, this type of sampling is conducted to support enforcement actions against an industrial user. This type of sampling activity is performed on an as needed basis.

The length of the sampling program depends on the flow, nature of the wastes, and type of samples (i.e., grab or composite) to be collected.

Typically, composite and grab samples are collected at each user site.

Nonpermitted Industrial Users (User Rate Charge Program) (Example Policy)

On a periodic basis (i.e., once every two to three years), commercial and minor industrial users are sampled to determine discharge concentrations of various pollutants. Typical types of users which may be sampled include: restaurants, photo processing laboratories, laundries, car washes, and printing shops.

A three- to four-day sampling program is usually conducted at each assigned site. Commercial establishments are sampled to establish BOD and SS levels for various groups of users for the Finance/ Utilities department.

This activity is also helpful in identifying industrial or commercial users which may discharge pollutants of concern.

Chapter 4 Sampling

The General Pretreatment Regulations require Control Authorities to monitor each SIU at least annually and each SIU to self-monitor semi-annually. As with inspections, the Control Authority should assess site-specific issues, such as SIU effluent variability, impact of this effluent on the POTW, and the SIU's compliance history to determine appropriate sampling frequencies (i.e., if more frequent monitoring is necessary).

For more detailed information on sampling frequencies, consult the EPA's 1994 *Industrial User Inspection and Sampling Manual for POTWs*.

Parameter	Sample type	Container	Preservative	Holding time
pH	Grab	Polyethylene or Glass	N/A	analyze immediately
BOD	Composite	Polyethylene or Glass	chilled to 4°C	48 hours
TSS	Composite	Polyethylene or Glass	chilled to 4°C	7 days
NH ₃ as N	Composite	Polyethylene or Glass	chilled to 4°C, H ₂ SO ₄ to pH<2	28 days
Oil and Grease	Grab	Glass	chilled to 4°C, HCl or H ₂ SO ₄ to pH<2	28 days
Cyanide, total	Grab	Polyethylene or Glass	chilled to 4°C, NaOH to a pH >12, and 0.6g of ascorbic acid if residual chlorine is present	14 days
Metals (total) excl. Cr ⁺⁶ , B, and Hg	Composite	Polyethylene or Glass	HNO ₃ to pH<2	6 months
624 (volatiles organics)	Grab	Amber glass, w/ Teflon septum lid and zero headspace	chilled to 4°C (additional laboratory preservation required)	7 or 14 days, depending on specific organic
625 (semi-volatile organics)	Composite	Amber glass w/ Teflon lined lid	chilled to 4°C (additional laboratory preservation required)	7 days for sample prep; 40 days for extract

Types of Samples

General

There are four types of samples that are collected by the POTW's Sampling Section: grab, time proportional composites, flow proportional composites, and hand composites. The sampling method used depends largely on the types of analyses to be run, and the nature of the wastestream being sampled. Each sampling method is described in this section.

Most POTW's will define the sampling methods which must be used by industrial users (**IUs**) to obtain representative samples to show compliance with their permits: **Example**

- (1) A grab sample is an individual sample collected in less than 15 minutes without regard for flow or time of day. pH, cyanide, oil and grease, sulfide, and volatile organics must be collected as grab samples.
- (2) 24-hour flow proportional composite samples where feasible. The POTW may waive this requirement if the IU demonstrates that this method is not feasible. Samples would then be taken by means of time proportional composite sampling methods, or by hand composite where the IU can demonstrate that this will provide a representative sample of the effluent being discharged.

The volume of sample to be collected by any of these methods is dependent on the number and types of analyses that must be performed.

Grab Samples

Grab samples are individual samples collected in less than 15 minutes without regard to flow or time of day. Grab samples are normally taken manually, but can be pumped. Oil and grease samples and purgeable organics are exceptions and must be taken manually. A grab sample is usually taken when a sample is needed to:

- (1) Provide information about an instantaneous concentration of pollutants at a specific time.
- (2) Quantify the pollutants in a non-continuous discharge (e.g., batch discharge).
- (3) Corroborate composite samples if the waste is not highly variable.
- (4) Monitor parameters not amenable to compositing such as pH, temperature, dissolved oxygen, chlorine, purgeable organics and sulfides, oil and grease, coliform bacteria, and sulfites.



Collecting Procedure for Water/Wastewater Grab Samples

- Lower dipper or mouth of the bottle into water just below surface. In some cases, you will need to rinse the bottle or dipper three times in the sample before obtaining the sample.
- Retrieve the collected sample to a clean processing area.
- Rinse the outside of the bottle 3 times to remove any contaminants.
- Pour the sample into the required laboratory bottle.
- You may need to filter the sample; this is true with some water and wastewater samples. Filtering (for ortho-P and NO_x samples)--some Surface water virus samples need to be filtered.
- Bottle preservation is performed in the truck or lab before sampling.
- Secure sample container caps tightly.
- Label the sample containers and place them in an iced cooler before storage.

Timed Composites

Timed samples are usually taken in instances where the intention is to characterize the wastes over a period of time without regard to flow, or where the flow is fairly constant.

Timed composite samples consist of a series of equal volume grab samples taken at regular intervals. Usually the interval is 15 minutes, with a maximum sampling duration of 24 hours.

However, other intervals can be used and may be more appropriate under some circumstances.

Samplers are available which can take up to 10 discrete samples per bottle, for a total of 240 discrete samples. The sampler may be programmed to take any number of samples into one composite bottle which has a 2.5-gallon capacity.

Flow Proportional Composites

Flow proportional composite samples consist of: a series of grab samples whose volumes are equal in size and proportion to the flow at the time of sampling. Samples are taken at varying time intervals, or continuous samples taken over a period of time based on the flow. Wherever possible, flow proportional sampling is recommended because it most accurately reflects the nature of the wastestream. Equal volume samples taken at varying time intervals are most often collected by the sampling inspectors. A flow measuring device must be used in conjunction with the automatic sampler.

This sampling method is used for all sampling activities except for instances where grab samples are required or time proportional sampling is more expedient and can provide the same accuracy as flow proportional sampling (i.e., constant flow levels).

Hand Compositing

Hand compositing is a series of time proportional grab samples which are collected and composited by hand. Provided the sample volumes are equal and are collected at even intervals, the results should be the same as if done by an automatic sampler (i.e., flow proportional composite sampling).

A specific instance where this sampling method may be used is in metal plating shops which have batch discharges from the treatment tank.

Provided the tank contains a homogeneous mixture, a minimum of four grab samples are taken of equal amounts and at evenly spaced intervals of time during discharge, to accurately represent the entire tank.

This should represent the waste characteristics of the entire batch discharge to the sewer. One hand composite per batch discharge would be equivalent to a 24-hour composite sample taken at other types of facilities. The sampling data would be compared with the average daily categorical standards or local limits where applicable.

Pre-Sampling Procedures

To ensure acceptable analytical results, numerous steps must be followed before a sampling program can be initiated:

- (1) Sampling equipment must be clean and be in good working order.
- (2) Sampling site must be selected.
- (3) Types of analyses must be determined.
- (4) Proper sample containers must be selected and prepared.

Sampling Equipment Example

The POTW may use one of the following portable samplers, ISCO Ultra-Sonic flow meters, SIGMA Depth Sensor samplers, and SIGMA pH Probe samplers. Safety equipment and other necessary equipment are also used.

The equipment that is kept in the sampling vehicle is dependent on the types of sampling activities planned each week, while the equipment stored in the storeroom is for back-up needs and future sampling demands.

Each sampling vehicle should be equipped with at least one sampler and one flow meter more than is needed for the particular sampling period. For example, three scheduled flow proportionate sampling sites would require a vehicle to be equipped with four samplers and four flow meters. At least one spare battery for each type of equipment taken into the field should also be placed in the sampling vehicle.

Auxiliary equipment, such as supports, harnesses, blowers, etc., that must be carried in each vehicle will depend on the nature of the sampling location.

In order to keep the equipment in good working order, the equipment should be maintained and cleaned on a regular basis. Routine maintenance and cleaning procedures should be written into your standard operating procedures.

Sampling Equipment Maintenance Example

Basic maintenance for samplers includes: periodic calibration and general equipment checking, and replacement of the internal desiccant and fuses. Routine cleaning should be done as covered in SOP.

Basic maintenance of the flow meters includes: periodic replacement of the internal desiccant, plotter paper, ribbon, fuses, and any broken re-roll spool assemblies. **Note: on the flow meters there are two tabs on the sides which are extremely thin and easily broken.**

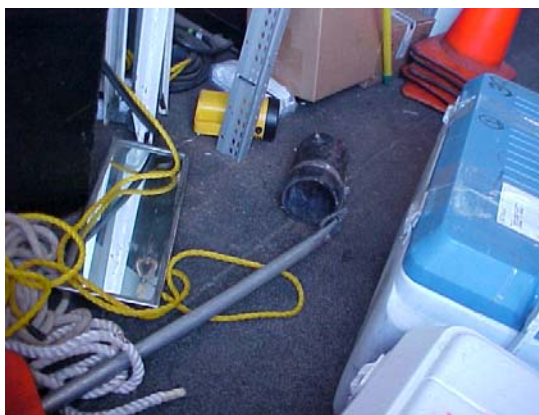
The NiCad and Gel Cell batteries need to be recharged on a regular basis. Any battery that reads less than 12.50 when checked should not be installed or left on any of the sampling equipment. At the battery charging station, areas are set aside for batteries that need to be charged and batteries already charged.

To prolong battery life, NiCad batteries should be fully discharged before recharging for a maximum of 24 hours, in accordance with the procedures described in the manufacturer's operations and maintenance manuals. Always bring a second set or back-up set of batteries with you.

It is important to note that charged NiCad batteries, if left unused for a long time, are nevertheless slowly discharging. Gel cell batteries are generally more stable. Voltage readings should be taken **before** the charged batteries are taken into the field to be sure that they still have a full charge.

When a sampler, flow meter, or ancillary equipment needs more specific repairs, the manufacturer representative should be contacted and arrangements made for repair or replacement of the equipment.

Inside Modern Wastewater Sampling Trucks



Wastewater sampler set-up in traffic to obtain composite sample from a sewer manhole. Notice the tri-pod and barricades.



Sampling

Sampling is the most appropriate method for verifying compliance with pretreatment standards. Monitoring location(s) are designated by the Control Authority and must be such that compliance with permitted discharge limits can be determined. Where possible, the Control Authority should not designate monitoring locations that are confined spaces or that are difficult to access or difficult to place the automated sampling equipment.

Monitoring locations should:

- be appropriate for waste stream conditions;
- be representative of the discharge;
- have no bypass capabilities; and
- allow for unrestricted access at all times.

Control Authorities should measure flow to allow for collection of flow-proportioned composite samples, which are required, unless flow-proportional sampling is not feasible. Flow-proportional composite samples are preferred over time composite samples particularly where the monitored discharge is intermittent or variable.

Desired analyses dictate the preparation protocols, equipment, and collection bottles to be used to avoid contamination of samples or loss of pollutants through improper collection. Sampling for such pollutants as pH, cyanide, oil and grease, flashpoint, and volatile organic compounds require manual collection of grab samples.

Similar to composite samples, grab samples must be representative of the monitored discharge and are to be collected from actively flowing wastestreams. Fluctuations in flow or the nature of the discharge may require collection of and hand-composting of more than one grab sample to accurately assess compliance.

To ensure defensibility of data, Control Authorities should develop and implement standard operating procedures and policies detailing sample collection and handling protocols in accordance with 40 CFR Part 136.

Adherence to proper sample collection and handling protocols, 40 CFR Part 136 approved analytical methodologies, and record-keeping requirements [40 CFR §403.12(o)(1)] (see Figure 25) can be verified through review of field measurement records, chain of custodies, and lab reports. Field measurement records may require information regarding sample location, condition of and programmed settings for sampling equipment, wastewater meter readings, and information for such parameters as pH and temperature which require analysis in the field.

Chain of custody forms serve as a link between field personnel and the laboratory and contain information regarding sample matrix, type, and handling. Lab reports should contain the minimum information specified in 40 CFR §403.12(o)(1)(ii-iv) as well as any additional information necessary to demonstrate compliance with 40 CFR Part 136 requirements (e.g., analytical methodology, sample preparation date and time, time of analysis).

Use of standardized forms which prompt recording of information necessary for demonstrating compliance with applicable requirements will aid in ensuring it can be used as admissible evidence in enforcement proceedings or in judicial actions.

Wastewater Sampling Information

Required Containers, Preservation Techniques, and Holding Times

40 CFR 136.3

Parameter No./name	Container	Preservation	Maximum holding time
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Table IA--Bacteria Tests:

1-4 Coliform, fecal and total. P,G..... Cool, 4C, 0.008% Na₂S₂O₃..... 6 hours.

5 Fecal streptococci..... P,G..... Cool, 4C, 0.008% Na₂S₂O₃ 6 hours.

Table IA--Aquatic Toxicity

Tests:

6-10 Toxicity, acute and chronic. P,G..... Cool, 4 deg.C 36 hours.

Table IB--Inorganic Tests:

1. Acidity..... P, G..... Cool, 4 deg. C..... 14 days.

2. Alkalinity..... P, G..... Cool, 4 deg. C..... 14 days.

4. Ammonia..... P, G..... Cool, 4 deg. C, H₂SO₄ to pH< 2..... 28 days.

9. Biochemical oxygen demand.. P, G..... Cool, 4 deg. C..... 48 hours.

10. Boron..... P, PFTE, or HNO₃ TO pH2..... 6 months. Quartz.

11. Bromide..... P, G..... None required..... 28 days.

14. Biochemical oxygen demand, P, G..... Cool, 4 deg. C..... 48 hours. carbonaceous.

15. Chemical oxygen demand.... P, G..... Cool, 4 deg. C, H₂SO₄ to pH<2..... 28 days.

16. Chloride..... P, G..... None required..... 28 days.

17. Chlorine, total residual.. P, G..... None required Analyze immediately.

21. Color..... P, G..... Cool, 4 deg. C..... 48 hours.

23-24. Cyanide, total and amenable to chlorination. P, G..... Cool, 4 deg. C, NaOH to pH>12, 0.6g Ascorbic acid 14 days.

25. Fluoride..... P..... None required..... 28 days.

27. Hardness..... P, G..... HNO₃ to pH<2, H₂SO₄ to pH <2..... 6 months.

28. Hydrogen ion (pH)..... P, G..... None required..... Analyze immediately.

31, 43. Kjeldahl and organic nitrogen. P, G..... Cool, 4 deg. C, H₂SO₄ to pH <2..... 28 days.

Metals:

18. Chromium VI..... P, G..... Cool, 4 deg. C..... 24 hours.

35. Mercury..... P, G..... HNO₃ to pH<2..... 28 days.

3, 5-8, 12, 13, 19, 20, 22, P, G..... do..... 6 months.

26, 29, 30, 32-34, 36, 37, 45, 47, 51, 52, 58-60, 62,63, 70-72, 74, 75. Metals, except boron, chromium VI and mercury.

38. Nitrate..... P, G..... Cool, 4 deg. C..... 48 hours.

39. Nitrate-nitrite..... P, G..... Cool, 4 deg. C, H₂SO₄ to pH <2..... 28 days.

40. Nitrite..... P, G..... Cool, 4 deg. C..... 48 hours.

41. Oil and grease..... G..... Cool to 4 deg. C, HCl or H₂SO₄ to pH <2 to 28 days.

42. Organic Carbon..... P, G..... Cool to 4 deg. C HCl or H₂SO₄ to pH <2 or 28 days.

44. Orthophosphate..... P, G..... Filter immediately, Cool, 4 deg. C. 48 hours.

46. Oxygen, Dissolved Probe... G Bottle and top. None required..... Analyze immediately.

47. Winkler..... G Bottle and top. Fix on site and store in dark... 8 hours.

48. Phenols..... G only..... Cool, 4 deg. C,..... H₂SO₄ to pH <2 28 days.

49. Phosphorus (elemental).... G..... Cool, 4 deg. C..... 48 hours.

50. Phosphorus, total..... P, G..... Cool, 4 deg. C, H₂SO₄ to pH <2.....28 days.

53. Residue, total..... P, G..... Cool, 4 deg. C..... 7 days.

54. Residue, Filterable..... P, G..... Cool, 4 deg. C..... 7 days.

55. Residue, Non-filterable P, G..... Cool, 4 deg. C..... 7 days.

56. Residue, Settleable(TSS)..... P, G..... Cool, 4 deg. C..... 48 hours.

57. Residue, volatile..... P, G..... Cool, 4 deg. C..... 7 days.

61. Silica..... P, PFTE, or Quartz..... Cool, 4 deg. C..... 28 days.

64. Specific conductance..... P, G..... Cool, 4 deg. C..... 28 days.

65. Sulfate..... P, G..... Cool, 4 deg. C 28 days.
 66. Sulfide.... P, G..... Cool, 4 deg. C add zinc acetate plus sodium hydroxide to pH>9. 7 days.
 67. Sulfite..... P, G..... None required..... Analyze immediately.
 68. Surfactants..... P, G..... Cool, 4 deg. C..... 48 hours.
 69. Temperature..... P, G..... None required..... Analyze.
 73. Turbidity..... P, G..... Cool, 4 deg. C 48 hours.

Table IC--Organic Tests

13, 18-20, 22, 24-28, 34-37, G, Teflon-lined septum Cool, 4 deg. C, 0.008% $\text{NA}_2\text{S}_2\text{O}_3$
 14 days.
 39-43, 45-47, 56, 76, 104, 105, 108-111, 113.
 Purgeable Halocarbons. 6, 57, 106.
 Purgeable aromatic hydrocarbons G, Teflon-lined septum Cool, 4 deg.C, 0.008% $\text{NA}_2\text{S}_2\text{O}_3$
 14 days.
 3, 4. Acrolein and acrylonitrile G, Teflon-lined septum Cool, 4 deg.C, 0.008% $\text{NA}_2\text{S}_2\text{O}_3$ pH 4-5 14 days.
 23, 30, 44, 49, 53, 77, 80, 81, 98, 100, 112. G, Teflon-lined Cool, 4 deg.C, 0.008% $\text{NA}_2\text{S}_2\text{O}_3$ 14 days.
 Phenols G, Teflon-lined septum Cool, 4 deg.C, 0.008% $\text{NA}_2\text{S}_2\text{O}_3$ pH 4-5 7 days until extraction; 40 days after
 extraction.
 7, 38. Benzidines G, Teflon-lined septum..... Cool, 4 deg.C, 0.008% $\text{NA}_2\text{S}_2\text{O}_3$ 7 days until extraction.
 14, 17, 48, 50-52. Phthalate G, Teflon-lined septum Cool, 4 deg.C..... 7 days until extraction; esters
 40 days after extraction.
 82-84. Nitrosamines G, Teflon-lined septumCool, 4 deg. C, 0.008% $\text{NA}_2\text{S}_2\text{O}_3$...Store in dark
 88-94. PCBs G, Teflon-lined septum Cool, 4 deg.C 7 days until extraction; 40 days after extraction.
 54, 55, 75, 79. Nitroaromatics G, Teflon-lined septum.....Cool, 4 deg.C, 0.008% $\text{NA}_2\text{S}_2\text{O}_3$ and
 isophorone
 1, 2, 5, 8-12, 32, 33, 58, 59, 74, 78, 99, 101. Polynuclear aromatic hydrocarbons. Cool, 4 deg.C, 0.008%
 $\text{NA}_2\text{S}_2\text{O}_3$Store in dark
 15, 16, 21, 31, 87. Haloethers G, Teflon-lined septum..... Cool, 4 deg.C, 0.008% $\text{NA}_2\text{S}_2\text{O}_3$ 7 days until
 extraction; 40 days after extraction.
 29, 35-37, 63-65, 73, 107. Chlorinated hydrocarbons G, Teflon-lined septum.....Cool, 4 deg.C, 7 days
 until extraction; 40 days after extraction.
 60-62, 66-72, 85, 86, 95-97, 102, 103. CDDs/CDFs aqueous: field and lab G..... Cool, 0-4 deg. C, pH9,
 0.008% $\text{NA}_2\text{S}_2\text{O}_3$ 1 year preservation.
 Solids, mixed phase, anddo..... Cool, 4 deg. C..... 7 days.tissue: field preservation..
 Solids, mixed phase, anddo..... Freeze, -10 deg. C..... 1 year.
 tissue: lab preservation.

Table ID--Pesticides Tests:

1-70. Pesticides \11\.....do..... Cool, 4 deg. C, pH 5-9 Do.

Table IE--Radiological Tests:

1-5. Alpha, beta and radium... P, G..... HNO_3 to pH2..... 6 months.

Polyethylene (P) or glass (G). For microbiology, plastic sample containers must be made of sterilizable materials (polypropylene or other autoclavable plastic).

Sample preservation should be performed immediately upon sample collection. For composite chemical samples each aliquot should be preserved at the time of collection. When use of an automated sampler makes it impossible to preserve each aliquot, then chemical samples may be preserved by maintaining at 4 degrees C until compositing and sample splitting is completed.

When any sample is to be shipped by common carrier or sent through the United States Mails, it must comply with the Department of Transportation Hazardous Materials Regulations (49 CFR part 172). The person offering such material for transportation is responsible for ensuring such compliance. For the preservation requirements of Table II, the Office of Hazardous Materials, Materials Transportation Bureau, Department of Transportation has determined that the Hazardous Materials Regulations do not apply to the following materials: Hydrochloric acid (HCl) in water solutions at concentrations of 0.04% by weight or less (pH about 1.96 or greater); Nitric acid (HNO₃) in water solutions at concentrations of 0.15% by weight or less (pH about 1.62 or greater); Sulfuric acid (H₂SO₄) in water solutions at concentrations of 0.35% by weight or less (pH about 1.15 or greater); and Sodium hydroxide (NaOH) in water solutions at concentrations of 0.080% by weight or less (pH about 12.30 or less).

Samples should be analyzed as soon as possible after collection. The times listed are the maximum times that samples may be held before analysis and still be considered valid. Samples may be held for longer periods only if the permittee, or monitoring laboratory, has data on file to show that for the specific types of samples under study, the analytes are stable for the longer time, and has received a variance from the Regional Administrator under Sec. 136.3(e). Some samples may not be stable for the maximum time period given in the table. A permittee, or monitoring laboratory, is obligated to hold the sample for a shorter time if knowledge exists to show that this is necessary to maintain sample stability. See Sec. 136.3(e) for details. The term "analyze immediately" usually means within 15 minutes or less of sample collection. Should only be used in the presence of residual chlorine.

Maximum holding time is 24 hours when sulfide is present. Optionally all samples may be tested with lead acetate paper before pH adjustments in order to determine if sulfide is present. If sulfide is present, it can be removed by the addition of cadmium nitrate powder until a negative spot test is obtained. The sample is filtered and then NaOH is added to pH 12.

Samples should be filtered immediately on-site before adding preservative for dissolved metals.

Guidance applies to samples to be analyzed by GC, LC, or GC/MS for specific compounds.

Sample receiving no pH adjustment must be analyzed within seven days of sampling.

The pH adjustment is not required if acrolein will not be measured. Samples for acrolein receiving no pH adjustment must be analyzed within 3 days of sampling.

When the extractable analytes of concern fall within a single chemical category, the specified preservative and maximum holding times should be observed for optimum safeguard of sample integrity. When the analytes of concern fall within two or more chemical categories, the sample may be preserved by cooling to 4 deg. C, reducing residual chlorine with 0.008% sodium thiosulfate, storing in the dark, and adjusting the pH to 6-9; Samples preserved in this manner may be held for seven days before extraction and for forty days after extraction. Exceptions to this optional preservation and holding time procedure are noted in footnote 5 (re the requirement for thiosulfate reduction of residual chlorine), and footnotes 12, 13 (re the analysis of benzidine).

If 1,2-diphenylhydrazine is likely to be present, adjust the pH of the sample to 4.0 $\pm$ 0.2 to prevent rearrangement to benzidine.

Extracts may be stored up to 7 days before analysis if storage is conducted under an inert (oxidant-free) atmosphere.

For the analysis of diphenylnitrosamine, add 0.008% NA₂S₂O₃ and adjust pH to 7-10 with NaOH within 24 hours of sampling.

The pH adjustment may be performed upon receipt at the laboratory and may be omitted if the samples are extracted within 72 hours of collection. For the analysis of aldrin, add 0.008% $\text{Na}_2\text{S}_2\text{O}_3$.

Sufficient ice should be placed with the samples in the shipping container to ensure that ice is still present when the samples arrive at the laboratory. However, even if ice is present when the samples arrive, it is necessary to immediately measure the temperature of the samples and confirm that the 4°C temperature maximum has not been exceeded.

In the isolated cases where it can be documented that this holding temperature cannot be met, the permittee can be given the option of on-site testing or can request a variance. The request for a variance should include supportive data which show that the toxicity of the effluent samples is not reduced because of the increased holding temperature.

Metals Sampling (Example Procedure)

Metals sampling will encompass a variety of individual samples within a sample, i.e., nickel, zinc, silver and others. As a general rule, metals samples need to be collected as a composite and preserved with 1:1 nitric acid to $\text{pH} < 2$.

If ICP (inductively coupled plasma) laboratory analysis will be used, a 500 ml sample is sufficient. ICP is used for a general scan; if more stringent detection limits are needed then furnace analysis is used.

If additional analysis is required, i.e., furnace method analysis, collect a 2 liter bottle of sample (instead of the 500 ml sample) and preserve with nitric acid.

Ice is not necessary for preservation, but it won't jeopardize the sample, either.

PARAMETER	CONTAINER	PRESERVATIVE	MAX. HOLDING TIME
Metals	P	HNO_3 to $\text{pH} < 2$	6 months

Common Wastewater Sample Collection Bottles



**625/608, 1657, TTO/Organics, TPH/Oil/Grease,
Smaller bottles-TOCs, VOCs, 601/602 and 502.2**



**NO₂/NO₃, Fluoride, Sulfide, Metals, BOD-TDS-TSS
Wide-mouth Sludge/Metals bottle**

Laboratory 123 W. Main St Sun City, Arizona 85541										LAB I.D. NUMBER																			
Sampler:										DATE:										PAGE 1 OF 1									
Company: Department: Address: Contact: Telephone:										Metals* See Attached										Number/Containers									
Sample Identification										Lab ID										EC Conductivity									
Date										Matrix										Sulfate									
Time										Time										Organo-Phosphorus Pest. (8141)									
Lead/Copper										TSS										Fecal Coliform MPN-HPC									
BOD/COD										Nitrate										Tot. Coliform MPN									
Nitrate + Nitrite										TKN / Ammonia										Surfactants (MBAS)									
VOC / THM's										Semi Volatil Organics (625)										Fluoride									
Chloride										Cyanide										RELINQUISHED BY:									
Signature:										Signature:										Signature:									
Time:										Time:										Time:									
Printed Name:										Printed Name:										Printed Name:									
Company										Company										Company									
SAMPLED RECEIVED BY:										SAMPLED RECEIVED BY:										SAMPLED RECEIVED BY:									
Signature:										Signature:										Signature:									
Time:										Time:										Time:									
Printed Name:										Printed Name:										Printed Name:									
Company										Company										Company									

Wastewater Treatment Plant Sampling

POTW samples are collected in accordance with the National Pollutant Discharge Elimination System (**NPDES**) permit which sets discharge limits for certain pollutants and specifies sampling frequencies and sample types.

The POTW is responsible for coordinating the plant sampling activity with laboratory personnel who prepare any special sampling bottles and laboratory appurtenances necessary (i.e. trip blanks, etc.) to complete the sampling objectives.

Plant Sampling Procedure (*Example Procedure*)

Set up two samplers at the plant influent channel and two samplers at the plant effluent channel. Two samplers are used to provide sufficient sample quantity and to minimize sampler failure. All sampling equipment must be prepared and cleaned as established in your POTW's procedures. Teflon hose is required. Sampling sites are specified in each plant's NPDES permit.

Collect the following composite samples at both sites.

- (1) **Metals Sample** - (one 2-liter plastic bottle)

Preserve with 1:1 nitric acid to a pH < 2. Store sample on ice at 4°C.

- (2) **Cyanide Sample** – (one 2-liter plastic bottle)

Collect the cyanide sample as a composite in accordance with NPDES permit. Check the sample for chlorine. If Cl_2 is present, use ascorbic acid to eliminate it. Add NaOH to a pH > 12. Store samples on ice at 4°C.

- (3) EPA Test Method 608 and 625ⁱ samples are informational samples only. These results are used for local limits data.

608 and 625 samples are collected as composite samples. At the influent channel: Collect one 1-liter amber glass bottle of each sample (608, 625). Check samples for chlorine. At the effluent channel: Collect one 4-liter amber glass bottle of each sample (608, 625). Check samples for chlorine. If Cl_2 is present in the samples, use sodium thiosulfate ($\text{Na}_2\text{S}_2\text{O}_3$) to eliminate it. Store samples on ice at 4°C.

- (4) **625/Phenols** are collected as a grab sample. Collect one 4-liter amber glass bottle at the effluent channel only. Check the sample for chlorine. If Cl_2 is present, use sodium thiosulfate ($\text{Na}_2\text{S}_2\text{O}_3$) to eliminate it. Store sample on ice at 4°C.

Bio-Solids Sampling (*Example Procedure*)

Bio-solids (dried sludge) samples are collected at POTWs.

Normally, bio-solid samples will be collected from the final storage area for dry sludge. The location of the dried bio-solids may vary based on the individual plants. Sampling frequency will be determined on an as needed basis and to comply with the EPA requirements.

All samples collected are grabs. All samples are collected using a sterile plastic scoop in order to avoid any contamination.

The following is a list of samples to be collected:

PARAMETER	CONTAINER
Helminth Ova & Enteric Virus	1 Qt Plastic Bag (Ziploc)
Metals +	500 ml Plastic Bottle
Nitrogen (total)	4 oz Glass Bottle
TOC (Total Organic Carbon)	4 oz Glass Bottle
Fecal Coliform	(autoclaved from lab)
6 hr hold time	500 ml Plastic Bottle

Sample Scheduling

An active file is maintained on each sampling location which contains historical data including past process discharge flow readings, water meter readings, sampling dates, and conditions of sampling site.

River Sampling Activities (*Example Procedure*)

When developing a sampling plan for river sampling, the following considerations must be observed:

- (1) Sampling sites must meet the objectives of the program or study.
- (2) At the sampling sites the river must be flowing freely and the sample must be as representative as possible of river flow at that site. Consideration of all safety factors must be observed.
- (3) Samples must be collected midstream of the main channel at approximately two-thirds of the depth unless specific depths have been requested.
- (4) All safety precautions must be observed during sampling which includes the use of harnesses, waterproof boots and other equipment.

Sewers (*Example Procedure*)

Sewer system and user rate sampling are conducted in manholes. General guidelines for selection of sampling locations include the following:

- (1) Samples should be taken at points of high turbulent flow to ensure good mixing and prevent the deposition of solids.
- (2) The sample location should be easily accessible and free of any major safety hazards.

- (3) Sample lines should not be located where there is surface scum.
- (4) If a flow study or a flow/proportional sampling event is required, make sure that the sewer pipe does not have a curve, a drop in the line or any obstructions. These would cause false readings.

Cleaning Automatic Samplers (*Example Procedure*)

Samplers, sample jars, grab beakers, and all other equipment used in collecting samples must be cleaned between their use at each site, to avoid the possibility of cross contamination. Latex or nitrile gloves should be worn to protect against infections and acid burns. The following steps should be taken to ensure the proper cleaning of the sampling equipment.

- (1) Break down the sampler and lay the three components in a row.
- (2) Place the strainers and weights in a plastic bucket.
- (3) Set the glass composite jars and Teflon caps off to the side, to be cleaned separately from the samplers.
- (4) Pour a small amount of diluted (1:128) O-Syl disinfectant and MICRO soap into each sampler component, the bucket containing the strainers and weights, and the composite jars.
- (5) To clean the sampler components:
 - (a) Partially fill the sampler bases and cover with water.
 - (b) Use a brush to scrub the inside and outside of each sampling component. Using a small bottle brush, thoroughly scrub the inside of the intake tube and the float housing of the sampler head (these are critical areas since they come in contact with the sample).
 - (c) Rinse off the soap with fresh water.
 - (d) Stack each component so that it will dry quickly and thoroughly.
 - (e) Reassemble the sampler after the components are dry, and store it in the proper compartment of the sampling van. Leave the sampler lid loose so moisture won't be trapped.
 - (f) Clean the strainers and weights in the bucket. Empty the contents of the bucket and rinse the bucket, strainers, and weights. After they have dried, place them in the proper storage areas of the sampling van.
 - (g) Drain the wastewater tank of the sampling van into the sewer drain.
 - (h) Refill the fresh-water tank on the sampling van with potable water.

Sampler Bottle Cleaning and Preparation (*Example Procedure*)

- (1) Fill each jar with O-Syl (same dilution as used in the sampler disinfection), MICRO soap, and fresh water.
- (2) Thoroughly scrub the inside and outside of the jars until they are sparkling clean. Make sure that all oil and grease are removed.
- (3) Rinse the jars with fresh water.
- (4) Pour a small amount of 1:1 nitric acid into one jar, and securely place the proper Teflon cap on the jar. Swirl the nitric acid throughout the jar, remove the lid, and pour the nitric acid into the next jar. Repeat this procedure until all the bottles have been treated. Rinse bottles with water after the acid wash. **NOTE: *Wear safety glasses or a full-face shield to protect your eyes.***
- (5) Place the jars in the drying oven. If the jars are to air dry, use Acetone to clean the bottles the same way as stated in (4) above. Let the jars and caps dry completely.
- (6) Place the jars, with their caps on loosely, in their respective places in the sampling van.

Selection of Sampling Site

In order to ensure the collection of valid samples, a representative sampling site must be selected. For industrial sampling, the sites are designated in the permit.



Direct deposit

Industrial Users - Permitted/Nonpermitted (*Example Procedure*)

The sampling points within an industry vary with each industry, depending on the nature of the process and location of pretreatment facilities. Therefore, exact locations must be identified on a case by case basis. However, the following general principles apply in all cases:

- (1) A permanent sampling location(s) must be identified for use by the POTW and the IU.

All permitted industries are required to install a sampling vault. The location of the vault is designated by the enforcement inspector. The enforcement inspector responsible for an individual company or site is responsible for providing directions (maps) to the specific sampling points, as well as current copies of permits and the name of the contact person and phone number. This information needs to be kept current in the sampling file.

Locations of sampling points need to be compared to what is listed on the current permit. If sampling points that the POTW is using do not agree with permit location, do not sample and refer to Chief Inspector or Supervisor.

- (2) The sampling location should be easily accessible and relatively free of safety hazards.
- (3) For categorical industries, there should be, if possible, no discharge present other than that from the regulated process. If other wastestreams are combined with the regulated wastestream prior to the sampling location, the combined wastestream formula will need to be utilized. The sampling crew must be aware of lower limits to correctly show analysis on chain of custody.
- (4) If the rate of industrial process discharge flow is needed (i.e., where mass limitations are applied), the sampling location will need to be located where the flow of the wastestream is known or can be measured or estimated and flow rates for the other wastestreams obtained.
- (5) In instances where sampling must be performed in the sewer outside of the building, the IU must install a sampling vault in accordance with Code.

Sample Type and Analyses

Typical sample volumes are required for various analyses. In addition, the laboratory has developed standard volumes for routine analyses performed on industrial waste samples as follows:

- (1) BOD/COD/TSS (1000-2000 ml, plastic)
- (2) Heavy metals (500-2000 ml, plastic)
- (3) Cyanide (2000 ml, plastic)
- (4) Oil and grease (1000 ml, level-one glass)

Selection and Preparation of Sample Containers

The selection of a sample container is based on the parameter to be measured. The inspector should be familiar with the type of sampling containers and preservatives that are needed.

It is essential that the sample containers be made of chemically resistant material, and do not affect the concentrations of the pollutants to be measured. In addition, sample containers should have a closure (i.e., leak proof/resistant, Teflon lined) that protects the sample from contamination and should be properly labeled before leaving the sampling site.

Sample Preservation

Wastewater usually contains one or more unstable pollutants that require immediate analysis or preservation until an analysis can be made. Sample preservation is needed for composite samples, for example, which may be stored for as long as 24 hours prior to transferring them to the laboratory. Recommended preservatives and holding times that should be used for specific pollutants are presented in the front of this Chapter.

Chain of Custody

Documentation of all pertinent data concerning the collection, preservation and transportation of samples is critical to the overall success of the Wastewater Sampling Program. If sampling is performed for the Pretreatment program, any sampling data may be used as evidence in court proceedings against a noncompliant industrial user. In this case, documentation becomes critical. This form is a legal document and is of major importance in a court hearing.

Specific procedures with regard to chain of custody are outlined below:

- (1) The sampling crew takes a sufficient supply of prenumbered Industrial Waste Lab Reports, (custody forms) and sample containers into the field.
- (2) The sampling crew fills in the sampling form at the time of sample collection, and returns the form to the lab along with the collected sample. Specific information to be completed on the form includes:
 - (a) CODE: The company ID number assigned by supervisor.
 - (b) SITE No.: The sampling point ID number assigned by supervisor.
 - (c) DATE SAMPLED: From - Date sampling began To - Date sample is pulled. If it is a grab sample, only the date the sample was taken will be entered with the other line crossed out.
 - (d) SUBMITTED BY: This will have a preprinted truck number. The sampling crew will write in their initials on the blank line which follows.
 - (e) LABEL: A letter is checked and the type of analysis to be performed. .
 - (f) PRESERVATIVE: The method of preservation used. See Table 8-5 to see which preservatives to use.
 - (g) TYPE SAMPLE: Check off whether flow proportional, timed composite, hand composite, or grab sample.
 - (h) TIME: The time frame needed for collection of the sample. A starting time for sample collection, an ending time, and a total time in hours and quarter hours is recorded, such as 23.25 hours. On a grab sample only, the end time, which is the time the sample was taken, will be entered and the other two lines will be crossed out.
 - (i) RELINQUISHED BY: This is the signature of person that relinquishes sample to lab personnel, or to any other person taking custody of the sample.
 - (j) DATE: Date sample is submitted to the laboratory or relinquished to another person.

- (k) NOTES TO LAB: Includes any special notes to the lab, such as special analysis required of the sample, a letter code which is assigned to the entity being tested, the amount of flow if sample is flow proportional, grab sample pH and temperature, and/or actual sample temperature.
 - (l) FIELD TEST: Results of any field tests including sample pH, hexavalent chromium, dissolved sulfides, copper, and residual chlorine. See Table 8-5 to see which field tests need to be performed on the sample.
 - (m) RESULTS: The appropriate box(es) need to be checked to correspond to the label designation chosen above.
- (3) When the sampling is completed at a site, the sampling crew labels the bottles with the label letter designation. The samples are sealed with chain of custody seals and placed in an ice chest for transportation to the lab.
 - (4) The sampling crew submits the samples and the chain of custody form to the laboratory.
 - (5) The laboratory logs the samples and assigns a Lab Reference Number to the sample. The sample is tracked by this number.
 - (6) Laboratory personnel sign and date the form, and return it to the sampling crew who makes two copies of the form. One copy is for the sampling crew files and the other is for data entry. The original form is returned to the laboratory. It is also important to note that the sampling vehicle should be kept locked at all times when the sampling crew is not in the vehicle, or in full view of the vehicle.

Quality Assurance/Quality Control (example)

Quality Assurance/Quality Control (**QA/QC**) measures taken by the sampling crew include equipment blanks, trip blanks, split samples and duplicate samples. Equipment blanks and trip blanks are routine QA/QC measures.

Split samples are taken for Local Limits sampling and when requested by an industry. Split samples requested by an industry are analyzed by their lab at their expense. Duplicate samples are run when requested by a Project Leader.

The laboratory prepares all trip blanks/travel blanks used by the sampling crews. This is performed in the laboratory rather than in the field in order to assure that there is no field contamination in the blanks.

Any contamination detected in the blanks would result from field exposure which could in turn affect collected samples.



In this photograph, an operator shows a group of Cub Scouts the quality of final effluent. A Pretreatment Inspector's work is reflected by the wastewater treatment system and the collection's system lack of problems. Most Wastewater Operators do not realize the benefits of having Pretreatment Inspectors protecting wastewater from illegal industrial and commercial discharges.

QA/QC Field Procedures for Plant Sampling (*Example*)

Duplicate Sampling Procedure

The purpose of Duplicate Samples is to check the laboratory's ability to reproduce analytical results. Duplicate Samples are to be collected using these steps:

1. Determine amount of sample needed. If a flow proportion sample is required, then base the amount of sample needed on the current flow reading. If a flow-proportion sample is not required, then use the predetermined amount for the sampling site.
2. Collect sample using a grab type sampler or a sampling head.
3. Measure the amount determined in Step 1 using a graduated cylinder or other accurate measuring device.
4. Pour measured sample into sample container that is not marked as the Duplicate Sample.
5. Measure same amount as in Step 1.
6. Pour second measured quantity into sample container marked for Duplicate Sample.
7. Process both samples using standard procedures and submit both samples to laboratory.

Split Sampling Procedure

The purpose of Split Samples is to check analytical procedures by having the samples analyzed by two different laboratories. Split Samples are to be collected using these steps:

1. Determine amount of sample needed. If a flow proportion sample is required, then base the amount of sample needed on the current flow reading. If a flow-proportion sample is not required, then use the predetermined amount for the sampling site.
2. Collect sample using a grab type sampler or a sampling head.
3. Measure the amount determined in Step 1 using a graduated cylinder or other accurate measuring device.
4. Pour measured sample into sample container that is not marked as the Split Sample.
5. Measure same amount as in Step 1.
6. Pour second measured quantity into sample container marked for Split Sample.
7. Process both samples using standard procedures and submit both samples to the laboratory. The laboratory will be responsible for submitting the samples to the outside laboratory that will be analyzing the Split Sample.

Trip Blank Procedure

The purpose of Trip Blanks is to determine if the sample bottles have been adequately cleaned, and if sample contamination occurs between the time sample bottles leave the laboratory to the time that samples are returned to the lab.

Trip blanks are prepared by the laboratory using bottles supplied by the sampler. They are picked up by the person who begins the sampling day. Trip blanks are placed in the cooler which contains the other samples, and remain there until the samples are turned into the laboratory.

Field Equipment Blank Procedure (*Example*)

The purpose of Field Equipment Blanks is to test the procedure for cleaning the sample measuring container to determine if cross contamination between sample sites has occurred. These Blanks are needed only at sites where flow-proportion samples are taken. Follow these steps when collecting a Field Equipment Blank:

1. Collect Field Equipment Blank **AFTER** collecting a sample and **BEFORE** moving to the next sampling location.
2. Open a sealed bottle of High Purity Water.
3. After collecting a sample, triple rinse the sample measuring container, usually a graduated cylinder, using High Purity water.
4. Pour the High Purity Water into the sample measuring container that was just rinsed.
5. Pour the High Purity water from sample measuring device into sample bottles labeled for the Field Equipment Blanks.
6. Repeat Steps 3 through 5 until all Field Equipment Blank sample bottles have been filled.
7. Process samples using standard procedures and submit to laboratory.

An equipment blank is high purity water which has been collected in a composite sample bottle or a series of discrete bottles from an automatic sampler. Equipment blanks are used to evaluate the reliability of composite samples collected in the field. The data produced from the equipment blank indicates the performance of the sample collection system, which involves the cleaning of sampling equipment, and accessories, preservation techniques, and handling of samples. The objective is to demonstrate that the samples are not contaminated by inadequate cleaning of equipment, contaminated preservation additives or sample collection techniques, and to provide documented records on Quality Assurance Practices.

Procedures to be followed in collecting the equipment blanks are outlined below. (Also see QA/QC check list, example).

- (1) The sampler is to be assembled completely in the manner determined by the parameters the crew will be sampling (i.e. if sampling for organics, Teflon suction tubing must be used at that site). The composite jar inside the sampler must always be rinsed out thoroughly with high purity water.
- (2) Program the sampler to collect the proper amount of high purity water that is representative of the sample parameters that will be collected at that site. Grab samples are excluded. Pump high purity water through the strainer and intake tubing prior to filling the sampler bottle. Then, place the strainer into as many fresh, uncontaminated bottles of high purity water as needed to collect the necessary volume of sample.
- (3) If the sampler is set up in the discrete mode, the crew must then transfer the collected samples into the field composite bottle and shake to mix thoroughly.
- (4) Transfer the sample from the field composite bottle into its respective lab sample bottles. Test and preserve the samples as appropriate for the parameters being analyzed.
- (5) Follow the chain of custody procedures outlined in SOP for turning the samples in to the laboratory. All paperwork must be completed at this time, and all bottles must be marked accordingly. Custody seals must be used. The crew must note the sampling activity in a logbook that is kept specifically for documenting preparation of equipment blanks and/or any other QA activities.

Sampling Techniques (*Example*)

General Guidelines

In general, the following guidelines should be observed in conducting sampling activities:

- (1) Samples being collected must be representative of the wastestream being tested.
- (2) Samples shall be collected in uncontaminated containers and preserved properly.
- (3) Samples should be of sufficient volume for the required analyses.
- (4) Samples should be stored in a manner which does not alter the properties of the sample prior to chain of custody transfer.
- (5) Samples should be properly and completely identified by marking them with the proper information.
- (6) Sample lines should be as short as possible and the smallest practical diameter to facilitate purging, reduce lag time, and give adequate consideration to maximum transport velocity. Also, they should have sufficient strength to prevent structural failure.
- (7) Sample lines should be pitched downward at least 10 percent to prevent settling or separation of solids contained by the sample.
- (8) Samples should be delivered as quickly as possible to the laboratory.

Specific Techniques

Sampling techniques in addition to the above general guidelines must also recognize differences in sampling methodology, preservation, and analytical methods.

The following sections specify techniques that differ by pollutant group and discuss such factors as sampling methodology (e.g., composite, grab, etc.), type of container, preservation and holding time.

Sampling Techniques for Volatile Organics (*Example*)

Volatile organics are analyzed in accordance with EPA methods 601, 602, 603 and 624.

Due to the volatility of these compounds, only grab samples can be taken. If a composite sample is needed, individual grab samples must be collected and composited in the laboratory prior to analysis.

The procedures that must be followed in taking these samples are outlined below.

NOTE: Gloves, clothing, face, and eye protection must be worn when handling volatile organics. In addition, the sampling crew must thoroughly clean those parts of the body that have been exposed to these materials.

- (1) For each sampling date, the lab will also provide two additional bottles to be used as a backup in case of breakage. These sampling vials are only good for one week. If any are unused, they must be returned to the lab for disposal.

- (2) The lab will provide one sample trip blank per sampling date. This bottle is to be kept on ice until the samples are submitted to the lab. At least one day prior to sampling, go to the lab and request the sample bottles (40 ml vials) for the specific sampling site, as indicated by the sampling plan. The laboratory will arrange to have the appropriate number of sample bottles prepared, based on the number of analyses to be performed. The sampling crew should make sure that all bottles are provided for these samples by the lab technicians.
- (3) Collect the sample in a clean glass beaker. Test for chlorine with the Hach test kit. If there is any chlorine residual, neutralize the chlorine with sodium thiosulfate ($\text{Na}_2\text{S}_2\text{O}_3$) and retest for chlorine. Repeat until there is no chlorine residual. Make notes on chain of custody sheet if extra amounts of sodium thiosulfate are required for neutralization.
- (4) Remove the vials from the ice. There will be two empty vials for the 601 sample and two vials with HCl for the 602. The HCl will already have been measured into the vials by the lab personnel.
- (5) Fill the vial to just overflowing in such a manner that no air bubbles pass through the sample as the vial is being filled. This is accomplished by pouring the sample from the beaker into the vial along the side of the vial to minimize the possibility of entrapping air in the sample. Do not rinse out or overfill the vials, this will wash out the preservative in the vial.
- (6) Seal the vial so that no air bubbles are entrapped in it. Remember to put the Teflon side of the cap facing down onto the vial.
- (7) To be sure there are no air bubbles, turn the vial upside down and tap it against the palm of the hand. Check to see if there are air bubbles along the sides or bottom of the vial. If there are bubbles, unseal the vial, top off the vial, and reseal. Check the vial again for the presence of bubbles.
- (8) All samples must be maintained at 4°C from the time of collection until the time of extraction. Custody seals must be placed on all samples, and all paper work must be filled out properly.
- (9) Return the sample bottles and QA/QC bottles to the laboratory the same day the sample is collected.

Acid/Base/Neutral Extractable Organics and Pesticides

Acid extractable organics are analyzed in accordance with EPA methods 604 and 625. Base/neutral extractable organics are analyzed in accordance with EPA method 625, or individual methods for various groups of compounds including EPA methods 605, 606, 607, 609, 611, and 612. Pesticides are analyzed in accordance with EPA method 608.

The procedures that must be followed in taking these samples are outlined below.

- (1) Samples must be collected in certified clean one-gallon amber glass bottles with Teflon lids.
- (2) No travel blanks or QA/QC bottles are required with the samples.
- (3) Grab samples must be collected in amber glass bottles. They do not have to be completely filled, but must be a minimum of 1/3 to 1/2 full. Bottles should not be prewashed with samples prior to filling.
- (4) For composite sampling, glass composite bottles must be used and precleaned. Teflon tubing must be used for the suction piping. The pump tubing must be medium grade silicone rubber.
- (5) The composite bottle in the sampler must be kept refrigerated (putting ice in the sampler) at 4°C. If amber glass is not used (i.e. 2 1/2-gallon clear composite sampler bottle), the sample must be protected from the light during collection and compositing. The compositing must be done in the field (i.e. when discrete sampling has been used).
- (6) All samples must be iced at 4°C from the time of collection until extraction.
- (7) The sample should be checked for the presence of chlorine using field test kits that provide results in accordance with EPA methods 330.4 and 330.5. If chlorine is determined to be present, 80 mg of sodium thiosulfate should be added to each bottle. The sample must be retested for chlorine. This procedure must be repeated until there is no residual of chlorine shown. The amount of sodium thiosulfate added must be noted on the chain of custody if in excess of 80 mg.
- (8) All necessary paperwork must be completed at sampling site. All bottles must be properly labeled, and have custody seals.



Sampling Techniques for Heavy Metals (Example)

- (1) Generally, all metal samples collected are to be composite samples, i.e., flow/composite, time/composite, or hand composite.
- (2) For composite sampling, place the lid on the bottle and agitate the bottle to completely mix the composite sample.
- (3) Transfer the required amount from the composite container to either a 500 ml or 2000 ml clean plastic bottle. Check the pH of the sample.

Note: For inductively coupled plasma (ICP) metal analysis, a 500 ml clean plastic bottle is required. For extra metals or metals by furnace, a 2000 ml clean plastic bottle is required.

- (4) Add nitric acid (1:1 solution) to the sample to reduce the pH to below 2.0. Usually, 2 ml/500 ml is sufficient. Recheck the pH to be sure it is below 2.0. Make a note on the lab sheet if more than two ml of acid is required to bring the pH below 2.0.
- (5) Label the sample bottle with the corresponding IW number and proper analysis code letter. Attach the custody seal to the sample, then store in the ice chest until transferred to the laboratory. Fill out the IW lab sheet with all the pertinent information, being careful to include all required parameters and the type of analysis required, e.g., ICP/furnace.
- (6) When a grab sample is necessary, rinse out the receiving sample bottle with an aliquot of the sample stream at least three times. Then fill the sample bottle and proceed with steps two through four described above.
- (7) When a split sample is requested (i.e., one for the samplers and one for the user), the composite sample is prepared as described in item one. Providing there is sufficient sample, a portion is transferred into the bottle provided by the user.
- (8) If more than one site is sampled per day, a clean composite container (i.e., two and one half-gallon glass jar), must be used at each site.
- (9) If a discrete sampler is being used, at the time of collection combine all the samples that have been collected into a single clean composite bottle. Then follow the preceding steps one through four, and refer to step six if a split is requested.



Cyanide (Example)

To assure that the sample can be analyzed for cyanide, no chlorine can be present in the sample. Procedures for taking cyanide samples are as follows:

- (1) This sample is normally a grab sample. The cyanide sample is a composite sample when collected as part of Priority Pollutants or Plant Sampling at the waste treatment plants.
 - (a) In the sampling file, check the industries' wastewater discharge permit and locate all cyanide (**CN**) sampling sites. If the sampling sites are located in a confined space, follow Confined Space procedures before collecting the sample or samples.
 - (b) Collect 2000 ml (maximum), 1000 ml (minimum), of CN sample into a type C plastic bottle.

NOTE: 2000 ml is the standard, but for batch dischargers 1000 ml is adequate.

- (c) Test the cyanide sample for pH and temperature with the pH meter. Record the results on the custody sheet (Industrial Waste (IW) lab sheet).
- (d) Test for chlorine with a **Hach Total Chlorine Test Kit** (the instructions are located in the kit)
- (e) If chlorine is present in the CN sample, neutralize it with Ascorbic Acid ($C_6H_8O_6$). For ascorbic acid neutralization, add $C_6H_8O_6$, a few crystals at a time, until five mls of sample in the test tube produces no color. Then add an additional 0.06 g of $C_6H_8O_6$ for each liter of sample volume.
- (f) Once all Cl_2 has been neutralized, preserve the sample with Sodium Hydroxide (NaOH) and raise the pH to >12. Verify the >12 pH with a pH meter or pH test strips.
- (g) Mark on the side of the CN sample bottle the IW Lab sheet number (using a water proof marker), and place a corresponding custody seal across the sample bottle tightened cap. Place a Cyanide label on the bottle if cyanide is suspected of being present in the sample.
- (h) Store the CN sample in the ice at 4°C and transport it to the laboratory.

Total Sulfides (Example)

- (1) The Total Sulfide sample is collected as a grab sample only. Use a clean 500 ml plastic bottle to collect the sample. This sample may be pumped into the sample container or collected directly from the discharge side of the sampling device.
- (2) Preserve the sample with 1 ml of 2N Zinc Acetate ($C_4H_6O_4Zn$) and then add Sodium Hydroxide (NaOH) to raise the pH > 9.
- (3) Label and seal the sample with a custody seal. Cool to 4°C.

Oil and Grease/TPH (*Example*)

Oil and grease samples are collected as two separate samples:

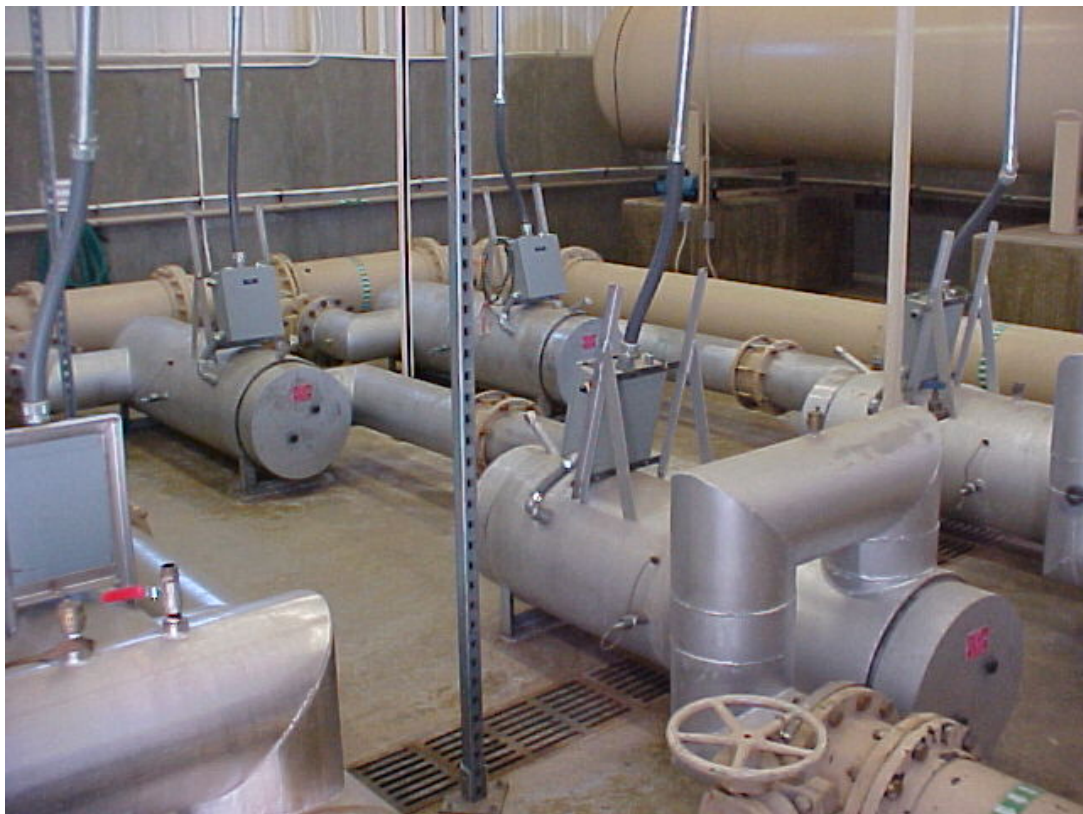
METHOD 413.1 (Oil and Grease). Non-volatile hydrocarbons: vegetable oils, animal fats, waxes, soaps, and related matters.

METHOD 418.1 (TPH). Extractable petroleum hydrocarbons: light fuels and mineral oils.

- (1) This is a grab sample only. The bottle used to take the sample must be the same bottle given to the laboratory for analysis. Do not pump or transfer the wastewater sample into the bottle. Obtain a clean 1000 ml glass bottle, do not use a pre-preserved bottle because you will lose the preservative when collecting the sample.
- (2) Collect the sample by placing the bottle neck down (up-side down) into the effluent stream below the surface. This should be as close to the discharge pipe or point as physically possible. Turn the bottle, allowing the bottle to fill, while keeping the bottle below the surface. Remove the filled bottle and cap it. Never skim the surface of the effluent stream.
- (3) Preserve the sample using five ml of sulfuric acid (H_2SO_4) for method 413.1 or hydrochloric acid (HCL) for method 418.1 (6:1 Ratio) to a pH of less than two. Reference 42 of methods 418.1 and 41 of methods 413.1. When more than five ml of HCL is used to lower the pH to less than two, make note of how much additional acid is used, and record this on the lab sheet. Also indicate required analyses method on lab sheet.
- (4) After making sure the sample is well mixed and preserved, seal and attach the proper identification (custody) label to the bottle. Then attach a custody seal across the lid. Store all samples at 4°C.
- (5) Under no circumstances are Inspectors to collect an oil and grease sample or any other grab sample for IUs.
- (6) All samples must be taken from a good representative flow. If there is any question as to whether there is sufficient flow for a representative sample, do not collect any sample. Make the necessary notes in the file report as to why no sample was obtained.

BOD/COD/SS (Example)

- (1) 24-hour composite sampling is always used for this test. Agitate the bottle to completely mix the composite sample. Do not allow the solids to settle out before you pour off the sample.
- (2) When more than one sample is being taken from a composite bottle, the BOD/COD/SS is taken first. The lab needs 1000 ml if the sample is cloudy or has solids. If the sample is clear, you must collect 2000 ml. Transfer the appropriate volume to the sample bottle.
- (3) Take the pH/temperature of the sample with either pH paper and a thermometer, or the pH meter carried on the sampling trucks.
- (4) Label the sample bottle and place a custody seal over the lid. Store on ice at 4°C.
- (5) Should split samples be requested, they are given when it is sure there is enough sample for POTW's requirements. Users must provide their own sample containers and allow POTW's staff to pour off samples.



Ultraviolet Trains at the end of the wastewater treatment cycle.

Virus Sampling (Example)

Viruses are microbiological organisms which can cause infectious diseases. Wastewater recharge and sewage disposal into the environment may contribute to the occurrence of viruses in surface water and groundwater. Viruses are the most mobile and infectious of the waterborne pathogens. Large volumes of water must be filtered to detect viruses. This involves passing the water samples through a cartridge filter by use of a gasoline driven pump.

(1) Equipment Needed

Most of the equipment required for virus sampling is available on the sampling trucks. However, some equipment is virus sampling specific. The needed equipment is as follows:

- (a) Gasoline/oil powered water pump
- (b) Hoses - intake (supplied with pump) and discharge (garden type, with female connectors at both ends)
- (c) Two 55-gallon plastic containers
- (d) Filter apparatus
- (e) Cartridge filters
- (f) Sodium thiosulfate (two 500 gram bottles/site)
- (g) Gasoline can with gas/oil mixture
- (h) Hach total chlorine test kit
- (i) Large plastic Zip-lock bags (supplied with cartridges)
- (j) Chain of custody sheets
- (k) Thermometer
- (l) Water-proof marker
- (m) Latex gloves
- (n) Liquid bleach
- (o) Cooler with blue ice
- (p) pH meter

(2) Sampling Procedure

Check the pump for gas/oil prior to starting (**do not fill while it is running**). Make sure the gas/oil mixture is correct by checking the mixing instructions on the side of the two-cycle pump oil can. Latex gloves should be worn for protection, and to prevent contamination of the filters.

Connect the hoses and filter housing (with no filter) to the pump, and run the effluent through it for one to two minutes to flush the system. Next, pump effluent into the two 55-gallon drums and rinse them out. (Note: If disinfection was not possible after the last sampling, then 50-100 gallons of effluent should be pumped through the entire equipment set up prior to placing the filter in the housing.)

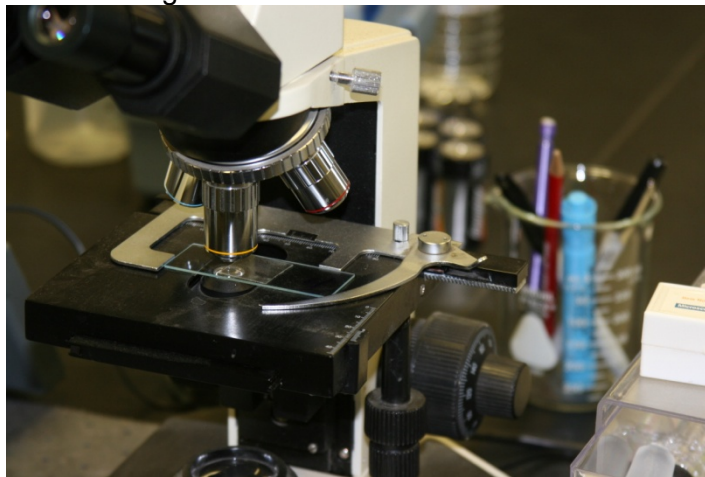
Pump effluent almost to the top (just above the handles) of both containers. While the drums are filling, check the water in the drums for chlorine using a Hach test kit and record the results and the temperature on the custody sheet. If chlorine is present and needs to be eliminated, add 500 grams of sodium thiosulfate to each container to eliminate it. After visual observation has determined that all the sodium thiosulfate has dissolved, retest to make sure there is a <0.1 ppm chlorine residual. If chlorine was removed, take the

hose from the channel, allow it to drain, and reprime the pump with the dechlorinated water.

Pump this water through the system to flush it, and adjust the flow to fill a one-gallon jug in about 15-20 seconds. Don't waste too much water, as the flow can be adjusted after the filter is inserted. Install the filter into the blue holder, being very careful not to touch it with your hands (wear clean latex gloves). There are two black washers that go with the filter, one on the bottom and the other on the top. Make sure these are aligned with the filter housing to prevent leaking. Screw the holder and filter onto the apparatus.

Refuel the pump, restart it, and adjust the water flow so that it is close to 15-20 seconds per gallon. Make sure the housing doesn't leak. Try to keep this amount of flow, since too great a flow will cause pass-through in the filter. Pump the water from both containers until they are empty. Stop the pump, remove the filter (wear clean latex gloves), and place it in its original zip-lock bag. The washers do not need to go with the filter, but if they fall into the bag it is better to leave them than take the chance of contaminating the filter trying to remove them. Fill in the information area on the zip-lock bag with a marker, indicating the plant being sampled and the date, and put it in the cooler with the blue ice provided. The blue ice keeps the temperature at 4°C to prevent significant die-off of the viruses.

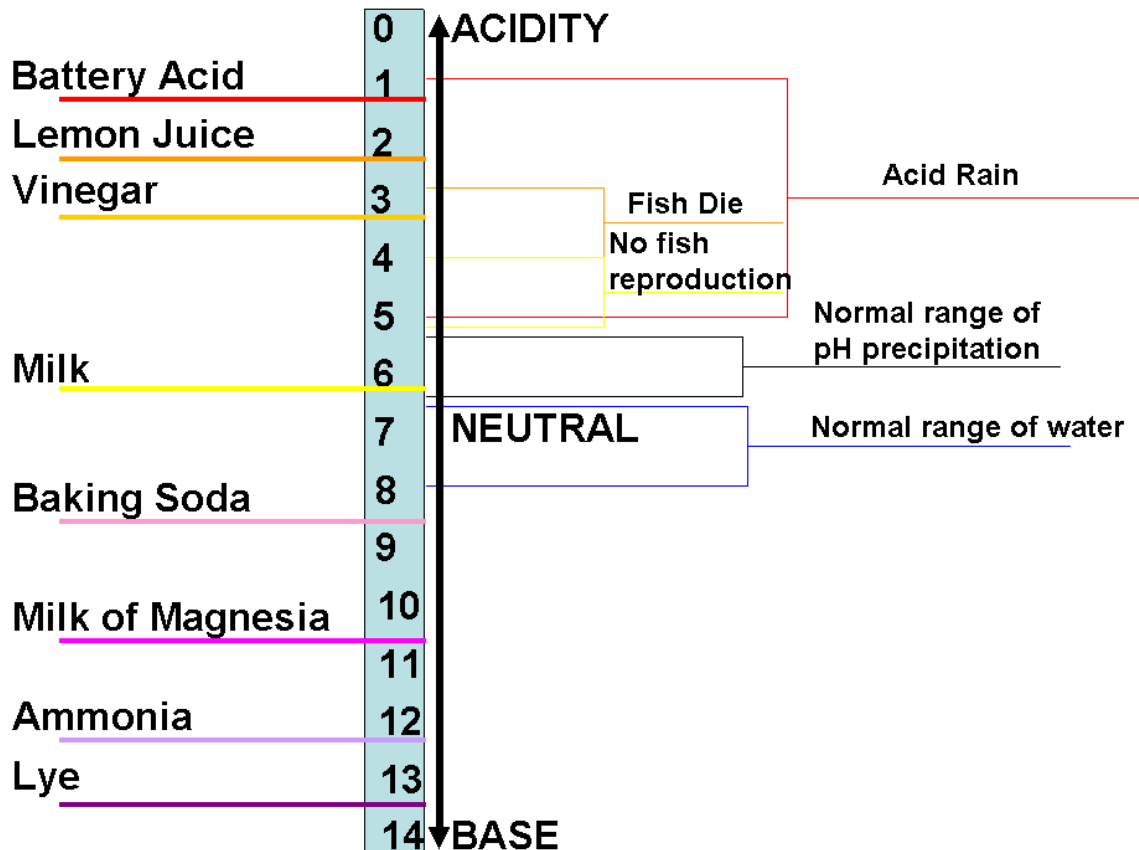
While at the site, or later at the plant, mix a half-gallon of bleach to 10 gallons of clean water. Pump it through the flow system and the containers. Rinse everything with fresh water and drain it so it is ready for the next time. Let the pump cool before storing it. Store the gas/oil mixture in the warehouse flammable storage cabinet.



Parasitology Sampling

Parasitology sampling utilizes the same equipment and techniques as in the virus sampling described above. However, a different type of filter, which is provided by the Lab, is used.

The pH Scale



pH: A measure of the acidity of water. The pH scale runs from 0 to 14 with 7 being the mid point or neutral. A pH of less than 7 is on the acid side of the scale with 0 as the point of greatest acid activity. A pH of more than 7 is on the basic (alkaline) side of the scale with 14 as the point of greatest basic activity.

pH = (Power of Hydroxyl Ion Activity).

The acidity of a water sample is measured on a pH scale. This scale ranges from **0** (maximum acidity) to **14** (maximum alkalinity). The middle of the scale, **7**, represents the neutral point. The acidity increases from neutral toward **0**.

Because the scale is logarithmic, a difference of one pH unit represents a tenfold change. For example, the acidity of a sample with a pH of **5** is ten times greater than that of a sample with a pH of **6**. A difference of 2 units, from **6** to **4**, would mean that the acidity is one hundred times greater, and so on.

Normal rain has a pH of **5.6** – slightly acidic because of the carbon dioxide picked up in the earth's atmosphere by the rain.

Field Tests

pH meter calibration examples, you should have a similar policy located with your pH meters.

There are several different pH meters on the market. For this course, two types of pH meters will be discussed--the 230A and the 250A models. A two-buffer calibration is used, 7 pH and 10 pH, since most of the tested samples fall within these ranges. Following are the methods presently used in the calibration and measuring techniques of these meters:

(1) Calibration of the Orion 230A Model pH Meter

- (a) Two-buffer calibration is used. The first calibration buffer liquid (pH 7) is near the electrode isopotential point, and the second (pH 10) is near the expected sample pH. Choose buffers that are no more than three pH units apart. Use fresh buffers at the beginning of each week.

This calibration should be done at the beginning of each day and the results entered in the pH logbook.

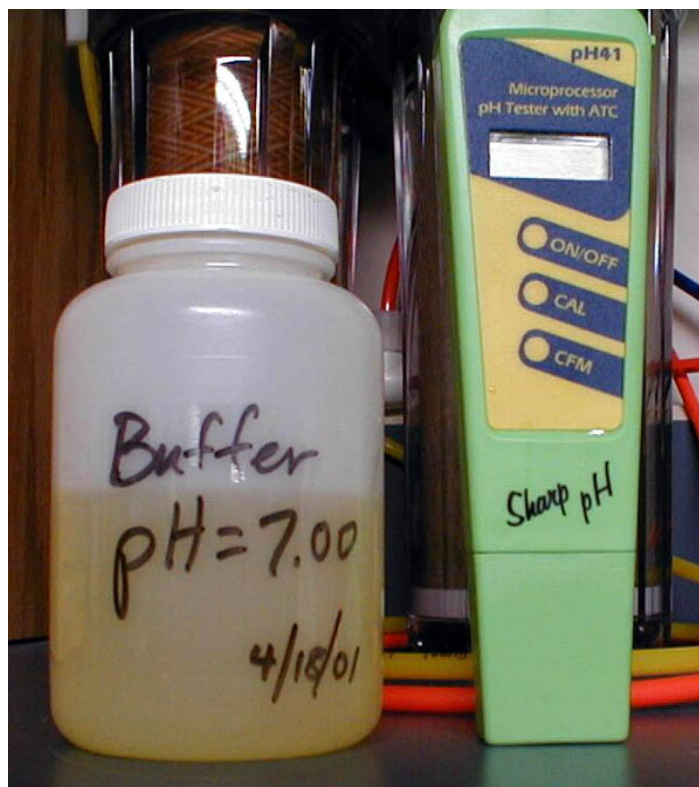
- (b) Uncover the fill hole. This should always be uncovered when using the meter and checked to make sure it is full of electrolyte solution. Turn on the meter's power. Rinse the electrode with high purity water then place it in the pH 7 buffer.
- (c) Press "**cal**". CALIBRATE and P1 will be displayed.
- (d) Wait for the meter to display **READY** with the pH reading flashing. If this is the correct pH, enter "yes" and proceed to step "E". If not, press the "**timer**" key and the first digit will start flashing. Pressing the "timer" or "setup" key ("timer" for raising the number or "setup" for decreasing it), correct the digit. When it is correct, press "yes." The second digit will start flashing. Repeat the previous steps for the second and third digits.
- (e) The display will now show P2, indicating the meter is ready for the second buffer. Rinse the electrode with high purity water and place it in the second buffer (pH 10). Wait for the meter to display **READY** with the pH reading flashing. Use the above procedure for calibrating at this pH.
- (f) The electrode slope, in percent, will be displayed (this value must be between 92 to 102 percent) along with the temperature. Record these figures in the logbook.
- (g) Rinse the electrode with high purity water and return it to the storage solution. Turn off the power. When the electrode won't be used for awhile, cover the fill hole with the rubber sleeve.

(2) Calibration of the Orion 250A Model pH Meter

- (a) This procedure is the same as the 230A Model through steps (a) and (b) above.
- (b) Press the "mode" key until the pH mode indicator is displayed. Place the electrode in the first buffer and press the "2nd" key. P1 will be displayed.
- (c) Go to step (d) in the calibration of the Orion 230A model and continue with the same set up.

(3) Measuring Techniques for pH with Orion Models 230A and 250A

- (a) Making sure the fill hole is uncovered, turn on the meter's power. Rinse the electrode with high purity water.
- (b) Place the electrode in the sample.
- (c) When the display is stable and shows READY, record the sample pH and temperature.
- (d) Rinse the electrode, return to the storage solution, and turn the power off. When finished for the day, cover the fill hole.



pH Meter pH scale is between 0-14. 0 being Acidic and 14 being Basic.
For fun, we measured Orange Juice and that is pH 3.5 or so - acid! We also measured Welch's Grape Juice and the meter showed 3.4 - also an acid (and slightly stronger). Here is a close-up of the pH41 meter we use and its pH 7.0 buffer solution (used for calibration and storage - there are a few drops of the buffer solution in the cap of the pH41 to keep it properly moist when not in use).

Sampling Procedures for Hexavalent Chromium (Hach Kit) (Example)

- (1) Rinse out the two color viewing tubes with a portion of the sample to be tested.
- (2) Refill one of the color viewing tubes to the 5 ml mark with a sample (this is the test sample). Using the clippers provided in the test kit, open one ChromaVer three chromium reagent powder pillow. Add the contents of the pillow to the sample. Stopper and shake to mix and put the tube in the color comparator.
- (3) Fill the other viewing tube with a sample and put it in the left side of the color comparator (this is the blank).
- (4) Let the viewing tubes sit in the color comparator for approximately 5 minutes. The samples should not be exposed to direct sunlight.
- (5) Hold the color comparator up to a light source and view the two samples through the two openings in the front. Rotate the dial on the holder until the color appears the same in both samples. Record the results from the dial (which is read in mg/l Cr +6) onto the chain of custody form.

Sampling Techniques for Dissolved Sulfides (Chemetrics, Inc. Kit) (Example)

- (1) Collect a 25 ml grab sample in the container provided.
- (2) Add three drops of activator (amber colored liquid) and mix well.
- (3) Break a sulfide chemet Type S glass ampule and add the contents to the 25 ml container.
- (4) Let stand five minutes.
- (5) Take a reading and record the results on the chain of custody form. If the reading is 0.0 then show the results less than 0.1 mg/l.

Sampling Techniques for Free and Total Chlorine (Hach Kit) (Example)

Procedures for determining free chlorine are as follows.

- (1) Rinse out the two color viewing tubes with a portion of the sample to be tested.
- (2) Refill one of the color viewing tubes to the 5 ml mark with a sample (this is the test sample). Using the clippers provided in the test kit, open one DPD free chlorine reagent powder pillow. Add the contents of the pillow to the sample. Stopper and shake to mix and put the tube in the color comparator. All of the powder does not have to dissolve to obtain correct readings.
- (3) Fill the other viewing tube with the original sample and put it in the left side of the color comparator (this is the blank).
- (4) Let the viewing tubes sit in the color comparator for approximately 1 minute. The samples should not be exposed to direct sunlight.

- (5) Hold the color comparator up to a light source and view the two samples through the two openings in the front. Rotate the dial on the holder until the color appears the same in both samples. Record the results from the dial (which is read in mg/l free chlorine) onto the chain of custody form.

Procedures for determining total chlorine are as follows.

- (1) Rinse out the two color viewing tubes with a portion of the sample to be tested.
- (2) Refill one of the color viewing tubes to the 5 ml mark with a sample (this is the test sample). Using the clippers provided in the test kit, open one DPD total chlorine reagent powder pillow. Add the contents of the pillow to the sample. Stopper and shake to mix and put the tube in the color comparator. All of the powder does not have to dissolve to obtain correct readings.
- (3) Fill the other viewing tube with a sample and put it in the left side of the color comparator (this is the blank).
- (4) Let the viewing tubes sit in the color comparator for approximately 3 minutes. The samples should not be exposed to direct sunlight.
- (5) Hold the color comparator up to a light source and view the two samples through the two openings in the front. Rotate the dial on the holder until the color appears the same in both samples. Record the results from the dial (which is read in mg/l total chlorine) onto the chain of custody form.

Dissolved Oxygen

Dissolved oxygen (**DO**) in water is not considered a contaminant. However, the (DO) level is important because too much or not enough dissolved oxygen can create unfavorable conditions. Generally, a lack of (DO) in natural waters creates anaerobic conditions. Anaerobic means without air. Certain bacteria thrive under these conditions and utilize the nutrients and chemicals available to exist. *Under anaerobic conditions the reaction is:*

Anaerobic:

Organics $\rightarrow$ intermediates + CO_2 + H_2O + energy

Where the intermediates are butyric acid, mercaptans and hydrogen sulfide gas. At least two general forms of bacteria act in balance in a wastewater digester. Saprophytic organisms and Methane Fermenters. The saprophytes exist on dead or decaying materials. The methane fermenters live on the volatile acids produced by these saprophytes. The methane fermenting bacteria require a pH range of 6.6 to 7.6 to be able to live and reproduce.

Aerobic:

Organics + Oxygen $\rightarrow$ CO_2 + H_2O + energy

Aerobic conditions indicate that dissolved oxygen is present. Aerobic bacteria require oxygen to live and thrive. When aerobes decompose organics in the water, the result is carbon dioxide and water. Dissolved Oxygen in a water sample can be detrimental to metal pipes in high concentrations because oxygen helps accelerate corrosion. Oxygen is an important component in water plant operations. Its primary value is to oxidize iron and manganese into forms that will precipitate out of the water. It also removes excess carbon dioxide. The amount of dissolved oxygen in a water sample will affect the taste of drinking water also.

Methods of Determination

There are two methods that we will be using in the lab. The membrane electrode method procedure is based on the rate of diffusion of molecular oxygen across a membrane. The other is a titrimetric procedure (Winkler Method) based on the oxidizing property of the (DO). Many factors determine the solubility of oxygen in a water sample. Temperature, atmospheric pressure, salinity, biological activity and pH all have an effect on the (DO) content.



Iodometric Test

The iodometric (titration) test is very precise and reliable for (DO) analysis of samples free from particulate matter, color and chemical interferences. Reactions take place with the addition of certain chemicals that liberate iodine equivalent to the original (DO) content. The iodine is then measured to the starch iodine endpoint. We then calculate the dissolved oxygen from how much titrate we use. Certain oxidizing agents can liberate iodine from iodides (positive interference), and some reducing agents reduce iodine to iodide (negative interferences). The alkaline Iodide-Azide reagent effectively removes interference caused by nitrates in the water sample, so a more accurate determination of (DO) can be made.

Methods of analysis are highly dependent on the source and characteristics of the sample. The membrane electrode method involves an oxygen permeable plastic membrane that serves as a diffusion barrier against impurities, only molecular oxygen passes through the membrane and is measured by the meter. This method is excellent for field testing and continuous monitoring. Membrane electrodes provide an excellent method for (DO) analysis in polluted, highly colored turbid waters and strong waste effluents. These interferences could cause serious errors in other procedures. Prolonged usage in waters containing such gases as H_2S tends to lower cell sensitivity. Frequent changing and calibrating of the electrode will eliminate this interference.

Samples are taken in BOD bottles where agitation or contact with air is at a minimum. Either condition can cause a change in the gaseous content. Samples must be determined immediately for accurate results. The dissolved oxygen test is the one of the most important analyses in determining the quality of natural waters. The effect of oxidation wastes on streams, the suitability of water for fish and other organisms and the progress of self-purification can all be measured or estimated from the dissolved oxygen content. In aerobic sewage treatment units, the minimum objectionable odor potential, maximum treatment efficiency and stabilization of wastewater are dependent on maintenance of adequate dissolved oxygen. Frequent dissolved oxygen measurement is essential for adequate process control.

Terms:

Aerobic (AIR-O-bick) a condition in which free or dissolved oxygen is present in the aquatic environment.

Aerobic Bacteria – (aerobes) bacteria which will live and reproduce only in an environment containing oxygen. Oxygen combined chemically, such as in water molecules (H_2O), cannot be used for respiration by aerobes.

Anaerobic (AN-air O-bick)- a condition in which “**free**” or dissolved oxygen is not present in the aquatic environment.

Anaerobic Bacteria – (anaerobes) bacteria that thrive without the presence of oxygen.

Saprophytic bacteria – bacteria that break down complex solids to volatile acids.

Methane Fermenters – bacteria that break down the volatile acids to methane (CH_4), carbon dioxide (CO_2) and water (H_2O).

Oxidation – the addition of oxygen to an element or compound, or removal of hydrogen or an electron from an element or compound in a chemical reaction. The opposite of reduction.

Reduction – the addition of hydrogen, removal of oxygen or addition of electrons to an element or compound. Under anaerobic conditions in wastewater, sulfur compounds or elemental sulfur are reduced to H_2S or sulfide ions

Procedure for Dissolved Oxygen Determination

METER-PROBE METHOD

1. Collect a water sample in the clean 300-ml glass stoppered BOD bottle for two or three minutes to make sure there are no air bubbles trapped in the bottle. Do one Tap water sample and one DI water sample. Mark the BOD bottles.
2. Insert the DO probe from the meter into your BOD bottles. Record the DO for Tap and DI water. Now continue with the Winkler Buret method.

PROCEDURES FOR WINKLER BURET METHOD

3. Add the contents of one **MANGANESE SULFATE** powder pillow and one **ALKALINE IODIDE-AZIDE** reagent powder pillow to each of your BOD bottles (TAP and DI)
4. Immediately insert the stoppers so that no air is trapped in the bottles and invert several times to mix. A flocculent precipitate will form. It will be brownish-orange if dissolved oxygen is present or white if oxygen is absent.
5. Allow the samples to stand until the floc has settled and leaves the solution clear (about 10 minutes). Again invert the bottles several times to mix and let stand until the solution is clear.
6. Remove the stoppers and add the contents of one **SULFAMIC ACID** powder pillow to each bottle. Replace the stoppers, being careful not to trap any air bubbles in the bottles, and invert several times to mix. The floc will dissolve and leave a yellow color if dissolved oxygen is present.
7. Measure 200 ml of the prepared solution by filling a clean 250-ml graduated cylinder to the 200-ml mark. Pour the solutions into clean 250-ml Erlenmeyer flasks. Save the last 100 mls for a duplicate.
8. Titrate the prepared solutions with PAO Titrant, 0.025N, to a pale yellow color. Use a white paper under the flask.
9. Add two droppers full of Starch Indicator Solution and swirl to mix. A dark blue color will develop.
10. Continue the titration until the solution changes from dark blue to colorless (end point). Go Slow- drop by drop. Record the buret reading to the nearest 0.01mls.
11. The total number of ml of PAO Titrant used is equal to the mg/L dissolved oxygen.

Dissolved Oxygen

Meter Results

1. Deionized water _____ mg/L
2. Tap water _____ mg/L
3. What is the meter procedure measuring?
4. What factors would determine which is the best method to use?
5. What are two forms of bacteria present in a wastewater digester?

Winkler Method Results

6. Deionized Water

200ml final Buret reading-
Sample initial Buret reading- - _____ = _____ mg/L

100ml final Buret reading-
duplicate initial Buret reading- - _____ dup= _____ mg/L
mls x 2

7. Tap water

200ml final Buret reading-
Sample initial Buret reading- - _____ = _____ mg/L
mls

100ml final Buret reading
Sample initial Buret reading- - _____ = _____ mg/L
mls x 2

8. What are some factors that can alter the (DO) content prior to testing?
9. Were your samples anaerobic or aerobic?
10. Why is it important to monitor the (DO) content of water and wastewater?

Be specific and give a detailed explanation.

Sludge Volume Index (SVI)

Sludge Volume Index Lab

The Sludge Volume Index (**SVI**) of activated sludge is defined as the volume in milliliters occupied by 1g of activated sludge after settling for 30 minutes. The lower the (SVI), the better is the settling quality of the aerated mixed liquor. Likewise, high (SVI) of 100 or less is considered a good settling sludge.

Calculation:

The results obtained from the suspended matter test and settleability test on aerated mixed liquor are used to obtain the SVI.

Calculation:

SVI=

$$\frac{\text{ml/L of sludge in settled mixed liquor in 30 min} \times 1000 \text{ mg/g}}{\text{mg/L of suspended matter in mixed liquor}}$$

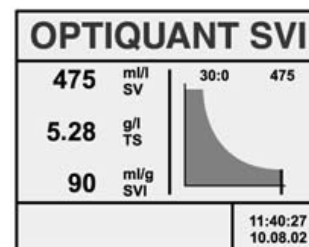
At last! Automated sludge volume index monitoring

Your wastewater treatment facility relies on timely monitoring of pH, flow, phosphate, ammonia, nitrate, or DO. Now, real-time assessment of sludge conditions with the new OptiQuant SVI™ Sludge Volume and Sludge Volume Index Analyzer complements these key control parameters.

Gone are manual samplings and hasty trips to the lab for analysis – it lets operators operate! No more re-mixing, dilutions, or questionable results. The SVI Analyzer's in-situ sampling yields an accurate, representative sample. It automatically detects bulking that signals upset conditions, gives operators better indication of upset root cause and corrective action, and provides on-the-spot response to chemical dosing adjustments. And the SVI Analyzer doesn't make more work for operators, because its unique sampling vessel construction discourages fouling. For complete information contact Hach at WWW.Hach.Com.



Operators select graphical or numeric SVI controller display. The controller and sampling vessel provide sludge volume monitoring, while an optional OptiQuant™ TS-line suspended solids probe allows automatic calculation of sludge volume index.



Suspended Matter for Mixed Liquor and Return Sludge

Suspended matter in mixed liquor and return sludge can be used to determine process status, estimate the quantity of biomass, and evaluate the results of process adjustments.

Apparatus

- Buchner funnel and adaptor
- Filter flask
- Filter paper 110 mm diam, Whatman 1-4
- 103° drying oven
- Desiccator
- Balance
- Graduated Cylinder

Procedure

1. Dry the filter papers in oven at 103°C to remove all traces of moisture.
2. Remove papers from oven and desiccate to cool for approximately 5 minutes.
3. Weigh to the nearest 0.01g and record the mass (W_1).
4. Place the paper in the bottom of the Buchner funnel and carefully arrange so that the outer edges lay snugly along the side. Be careful not to touch it with your finger. Use a glass rod. Wet the paper, turn on the vacuum and make a good seal, make a pocket covering the bottom of the funnel.
5. Add 20 to 100 mls of sample at a sufficient rate to keep the bottom of the funnel covered, but not fast enough to overflow the pocket made by the filter paper. Record the Volume used.
6. Remove the filter paper with tweezers. Dry in a 103°C oven for 30 minutes. Remove and desiccate. Reweigh the filter paper (W_2) to the nearest 0.01g.

Calculation:

mg/L Suspended Matter

$$\frac{(W_2) - (W_1) \times 1000 \text{ ML/L}}{\text{ML Sample}}$$

Where: (W_1) and (W_2) are expressed in mg.
(W_1) = mass of the prepared filter.
(W_2) = mass of the filter and sample after the filtration step.

Settleability Lab

The settled sludge volume of a biological suspension is useful for routine activated sludge plant control. Variations in temperature, sampling and agitation methods, diameter of settling column, and time between sampling and start of the test can significantly affect results. The same procedure and apparatus should be used each time the test is performed.

Apparatus

- Two settling columns with a minimum volume of 1000 ml
- A 1000 ml or larger graduated cylinder or Mallory settlometer may be used as a settling column.

Procedure

The settleability test on activated sludge should be run immediately after the sample is taken. The mixed liquor sample should be taken at the effluent end of the aeration tanks, while the return sludge sample should be taken at some point between the final settling tank and the point at which the sludge is mixed with primary effluent.

1. Determine the settleability of mixed liquor and return sludge by allowing 1000 mls of well mixed samples of each to settle in 1000 ml grad. cylinder or Mallory settleometer. Care should be taken to minimize floc break up during the transfer of the sample to the cylinder.
2. After 30 minutes, record the volume occupied by the sludge to the nearest 5 ml.
3. The reading at the end of 30 minutes is generally used for plant control. Although the settleability test on return sludge is not used in any of the calculations for activated sludge, the result is helpful in determining whether too much or too little sludge is being returned from the final settling tank.

Calculation: % Settled Sludge

$$\frac{\text{ml of sludge in settled mixed liquor or return sludge} \times 100}{1000}$$

Sludge Volume Index Lab Report Worksheet

Suspended Matter Calculations:

(W₁) = _____ mg Duplicate (W₁) = _____ mg

(W₂) = _____ mg (W₂) = _____ mg

mls Sample = _____ mls Sample = _____

mg/L suspended matter = _____ dup. _____

Settleability Calculations:

% settled sludge = _____

$$\frac{(\text{ml of sludge in settled mixed liquor or returned sludge} \times 100)}{1000}$$

Sludge Volume Index Calculations:

$$\frac{(\text{ml of sludge in settled mixed liquor in 30 minutes} \times 1000 \text{ mg/g})}{\text{mg/L of suspended matter in mixed liquor}}$$

Chapter 4 Enforcement

In addition to requirements for permitting, sampling, and inspecting IUs, the General Pretreatment Regulations also require Control Authorities to review IU reports and plans, and respond to instances of IU noncompliance in a timely, fair, and consistent manner. Enforcement of pretreatment requirements is a critical element of the Pretreatment Program, but in the past extenuating circumstances may have prevented POTWs from taking adequate enforcement.

For example, political and economic pressures from local officials could keep POTW personnel from taking appropriate actions. After this was identified as a major concern, the EPA promulgated regulations in 1990 (*55 FR 30082*) that require all POTWs with approved pretreatment programs to adopt and implement an Enforcement Response Plan (**ERP**).

These ERP regulations, at 40 CFR §403.8(f)(5), established a framework for POTWs to formalize procedures for investigating and responding to instances of IU noncompliance. With an approved ERP in place, POTWs can enforce against IUs on a more objective basis and minimize outside pressures.

IU Compliance

To evaluate IU compliance, Control Authorities must first identify applicable requirements for each IU. In general, IU reports (discussed in Chapter 5) and POTW monitoring activities are the basis for POTW evaluation of IU compliance. Discharge permit limit exceedances, discrepancies, deficiencies, and lateness are all violations that must be resolved.

To ensure enforcement response is appropriate and the Control Authority actions are not arbitrary or capricious, the EPA strongly recommends that an Enforcement Response Guide (**ERG**) be included as part of the approved ERP. The ERG identifies responsible Control Authority officials, general time frame for actions, expected IU responses, and potential escalated actions based on:

- The nature of the violation
- Pretreatment standards
- Reporting (late or deficient)
- Compliance schedules
- Magnitude of the violation
- Duration of the violation
- Frequency of the violation (isolated or recurring)
- (potential) impact of the violation (e.g., interference, pass through, or POTW worker safety)
- Economic benefit gained by the violator
- Attitude of the violator

How Complete is Your ERG?

Q: Is a Control Authority response required for all violations identified?

Q: Is the IU notified by the Control Authority when a violation is found?

Q: Is the IU required to respond to each violation with an explanation and, as appropriate, a plan to correct the violation within a specified time period?

Q: Where noncompliance continues and/or the IU response is inadequate, does the Control Authority's response become more formal and commitments (or schedules, as appropriate) for compliance established in an enforceable document?

Q: Is the enforcement response selected related to the seriousness of the violation?

Q: Where the violation constitutes SNC, and is ongoing, is the minimum response an administrative order?

The types of questions that dictate whether an ERP is adequate are presented above. Factors that should be considered in determining appropriate enforcement responses to noncompliance events are discussed in detail in the EPA's 1989 *Guidance for Developing Control Authority Enforcement Response Plans*.

The General Pretreatment Regulations set as an enforcement priority, facilities that meet the criteria for "**Significant Noncompliance (SNC)**" as defined in 40 CFR §403.8(f)(2)(vii) and depicted in Figure 27. A decision to seek formal enforcement is generally triggered by an unresolved instance of SNC, failure to achieve compliance in a specified time period through less formal means, or the advice of legal counsel.

SNC evaluations are to be conducted in six-month increments; names of IUs found to be in SNC must be published in the local newspaper (see Public Participation in this Chapter).

Formal enforcement must be supported by well-documented records of the violations and of any prior efforts by the Control Authority to obtain compliance. Where effluent limitations have been exceeded, records must be reviewed to verify compliance with 40 CFR Part 136 test methods. If the IU has received conflicting information from the Control Authority regarding its compliance status, its status must be clarified in writing.

Although not required, the Control Authority may consider a "**show cause**" meeting with the IU before commencing formal enforcement action. Similarly, the regulations do allow, in certain instances, an affirmative defense for violations. The range of enforcement mechanisms available to a Control Authority depends on the specific legal authorities it has been given by city, county, and State legislatures. These mechanisms may range from a simple telephone call to suits seeking significant criminal penalties. Common enforcement mechanisms include:

Informal notice to IU - This may consist of a telephone call or "**reminder**" letter to an appropriate IU official to notify them of a minor violation and to seek an explanation.

Such informal notice may be used to correct minor instances of noncompliance.

Administrative Tools

Informal meetings - Used to obtain an IU's commitment to comply with their pretreatment obligations or to inform the IU of stronger enforcement mechanisms available for unresolved and/or continued, noncompliance.

Warning letter or Notice of Violation (NOV) - Written notice to the IU in response to a violation of pretreatment standards or requirements. These notices should request an explanation of the noncompliance and measures that will be taken to eliminate future violations.

Administrative orders and compliance schedules - These require an IU to "**show cause**" to the Control Authority as to why formal enforcement action should not be taken and/or sewer service discontinued, or actions that will be taken to comply with pretreatment standards or requirements. Orders as such may be negotiated (i.e., Consent Order) or issued at the reasonable discretion of the Control Authority (i.e., Compliance Order).

For more egregious or serious violations, the Control Authority may issue a Cease and Desist Order.

Administrative fines - Assessed by Control Authorities against IUs for violations and intended to recapture partial or full economic benefit for the noncompliance and to deter future violations.

Civil suits - Formal process of filing lawsuits against IUs to correct violations and to obtain penalties for violations. Civil penalty amounts are generally limited through State or municipal laws. However, 40 CFR §403.8(f)(1)(vi) requires that Control Authorities have the legal authority to seek or assess civil or criminal penalties of at least \$1,000 per day for each violation.

A civil suit for injunctive relief may be used when the IU is unlikely to successfully execute the steps that the Control Authority believes are necessary to achieve or maintain compliance, when the violation is serious enough to warrant court action to deter future similar violations, or when the danger presented by an IU's lengthy negotiation of a settlement is intolerable.

NOTE: Surcharges are not penalties or fines. Surcharges are intended to recoup the cost of treatment of wastes by the POTW and must not be used to allow discharges of toxic pollutants that cause interference or pass through.

Definition of Significant Noncompliance (SNC) An IU is in SNC if its violation meets one or more of the following criteria (40 CFR 403.8(f)(2)(vii):

- (A) Chronic violations of wastewater discharge limits, defined here as those in which sixty-six percent or more of all of the measurements taken during a six-month period exceed **(by any magnitude)** the daily maximum limit or the average limit for the same pollutant parameter;
- (B) Technical Review Criteria (TRC) violations, defined here as those in which thirty-three percent or more of all of the measurements for each pollutant parameter taken during a six-month period equal or exceed the product of the daily maximum or the average limit multiplied by the applicable TRC (TRC = 1.4 for BOD 5, TSS, fats, oil, and grease, and 1.2 for all other pollutants except pH);
- (C) Any other violation of a pretreatment effluent limit (**daily maximum or longer-term average**) that the Control Authority determines has caused, alone or in combination with other discharges, interference or pass through (including endangering the health of POTW personnel or the general public);
- (D) Any discharge of a pollutant that has caused imminent endangerment to human health, welfare or to the environment or has resulted in the POTW's exercise of its emergency authority under 40 CFR § 403.8(f)(1)(vi)(B) of this section to halt or prevent such a discharge;
- (E) Failure to meet, within 90 days after the schedule date, a compliance schedule milestone contained in a local control mechanism or enforcement order for starting construction, completing construction, or attaining final compliance;

- (F) Failure to provide, within 30 days after the due date, required reports such as baseline monitoring reports, 90-day compliance reports, periodic self-monitoring reports, and reports on compliance with compliance schedules;
- (G) Failure to accurately report noncompliance;
- (H) Any other violation or group of violations which the Control Authority determines will adversely affect the operation or implementation of the local pretreatment program.

Criminal Prosecution

This type of enforcement is a formal judicial process where sufficient admissible evidence exists to prove beyond a reasonable doubt that a person has willfully or negligently violated pretreatment standards or that a person has knowingly made a false statement regarding any report, application, record, or other document required by the General Pretreatment Regulations.

As noted above, Control Authorities must have the legal authority to seek or assess civil or criminal penalties of at least \$1,000 per day for each violation. Examples of criminal violations include falsification of data and tampering with sampling results or equipment.

Termination of service (revocation of permit) - These actions may be pursued by Control Authorities to immediately halt an actual or threatened discharge to the POTW that may represent an endangerment to the public health, the environment, or the POTW. Use of these remedies may also be used in bringing recalcitrant users into compliance.

Regardless of the response taken, the Control Authority should document and track all contact, notices, and meetings with IUs and IU responses. Control Authority responses and IU responses (or lack thereof) should be documented and include a record of any direct contact with the IU to attempt to resolve the noncompliance.

Control Authorities must take timely and effective enforcement against violators. Unresolved IU noncompliance may result in the Approval Authority enforcing directly against the IU and/or the Control Authority. The EPA may also take enforcement action where it deems action by the State or the Control Authority is inappropriate. An Approval Authority will routinely review the overall performance of a Control Authority in monitoring IUs, identifying violations, and in enforcing regulations.



Performance will be evaluated based on POTW self-monitoring data, written enforcement response plans, audits, inspections, and pretreatment program reports. Therefore, it is essential for Control Authorities to effectively manage program information to demonstrate proper implementation. Section 505 of the CWA allows citizens to file suit against a Control Authority that has failed to implement its approved pretreatment program as required by its NPDES permit. The Control Authority may be fined as well as required to enforce against violations of pretreatment standards and requirements in a court order.

ENFORCEMENT RESPONSE PLAN EVALUATION CHECKLIST

Name of POTW:	Date of Review:
----------------------	------------------------

Requirement	YES	NO	N/A	Section Reference
A. Does the Enforcement Response Plan (ERP) describe how the POTW will investigate instances of noncompliance?				
1. Does it indicate that inspections and sampling will be used as a means to identify IU noncompliance?				
2. Does it indicate that inspections and sampling will be used as a means to follow-up on IU noncompliance?				
3. Does it identify personnel responsible for conducting inspections and sampling?				
4. Does it identify personnel responsible for entering inspection and sampling results into the IU's file?				
5. Does it specify time frames for entering inspection and sampling data?				
6. Does it describe procedures for tracking and reviewing (including evaluating report completeness and accuracy) all IU reports and notifications?				
7. Does it specify personnel responsible for reviewing reports and notifications?				
8. Does it specify personnel responsible for recommending enforcement action?				
9. Does it describe procedures for tracking responses to enforcement actions?				
10. Does it include appropriate procedures for determining violations and calculating SNC based on continuous pH monitoring?				
11. Does it clearly indicate the enforcement response that will be taken in response to SNC, including causing interference, pass through, filing late reports, etc.?				
12. Does it indicate that the POTW will respond to instances of SNC with an enforceable order within 30 days of identification?				
B. Does the ERP describe the types of escalating enforcement responses the POTW will take in response to all anticipated types of violations?				
1. Does it identify all possible types of noncompliance, including:				
a. Discharge without a permit (no harm)				
b. Discharge without a permit (harm)				
c. Failure to renew permit				

Requirement		YES	NO	N/A	Section Reference
d.	Isolated violations of discharge limit (no harm)				
e.	Isolated violations of discharge limit (harm)				
f.	Recurring violation of discharge limit (no harm)				
g.	Recurring violation of discharge limit (harm)				
h.	Reported slug load (no harm)				
i.	Reported slug load (harm)				
j.	Late report				
k.	Report is incomplete				
l.	Failure to monitor all regulated pollutants				
m.	Report is improperly signed or certified				
n.	Failure to submit a report or notice				
o.	Falsification of data				
p.	Use of improper sampling procedures				
q.	Failure to install monitoring equipment				
r.	Missed compliance schedule milestones (no effect on final compliance date)				
s.	Missed compliance schedule milestones (effect on final compliance date)				
t.	Use of dilution instead of treatment				
u.	Failure to properly operate and maintain pretreatment equipment				
v.	Denial of entry to POTW personnel				
w.	Failure to maintain records				
x.	Failure to report additional monitoring				
2.	Does the ERP reflect the full range of enforcement responses that are allowed under State law and the POTW's sewer use ordinance?				
3.	Does the POTW's sewer use ordinance provide adequate legal authority for all enforcement actions the POTW proposes to initiate?				
4.	When identifying appropriate enforcement actions, does the ERP allow for consideration of the following factors?				
a.	Magnitude of the violation				
b.	Duration of the violation				
c.	Effect on receiving water				
d.	Effect on POTW				
e.	IU's compliance history				
f.	IU's good faith				

Requirement	YES	NO	N/A	Section Reference
5. Does the ERP adequately describe procedures for escalating enforcement responses?				
6. Does the ERP include associated time frames for all activities including data review, initial and escalated enforcement actions, and follow-up actions?				
7. Does the ERP indicate that data will be reviewed no later than 5 working days after its receipt?				
8. Does the ERP indicate that initial enforcement actions will be taken no more than 30 days after detection of a violation?				
9. Do the proposed time frames in the ERP for initial enforcement actions make sense? For example, will NOV's be issued more promptly than more stringent enforcement action?				
10. Does the ERP allow for strong enforcement action to be taken immediately in the event of a major violation?				
11. Does the ERP indicate that initial follow-up compliance activities (e.g., inspections, sampling) will occur no later than 30 to 45 days after taking initial enforcement action?				
12. If the violation persists, does the ERP specify that escalating enforcement actions will be taken 60 to 90 days after the initial enforcement action?				
C. Does the ERP identify by title the persons responsible for each enforcement response?				
1. Are the positions described in the ERP consistent with those described in the POTW's program implementation procedures and sewer use ordinance?				
2. Do the positions identified in the ERP allow enforcement actions to be initiated in a timely and effective manner?				
D. Is the POTW's responsibility to enforce all pretreatment standards and requirements reflected in the ERP?				
1. Do the enforcement procedures in the ERP allow for final resolution of noncompliance? For example, is there a procedure to ensure that the same enforcement action will not be taken again and again without final resolution?				
2. Are the procedures identified in the ERP consistent with those contained in the program implementation procedures and sewer use ordinance?				

Requirement	YES	NO	N/A	Section Reference
E. In general, are the relevant elements of the ERP referenced and incorporated into other sections of the implementation manual?				



GRAB SAMPLE: A sample which is taken from a water or wastestream on a one-time basis with no regard to the flow of the water or wastestream and without consideration of time. A single grab sample should be taken over a period of time not to exceed 15 minutes.

Data Management and Recordkeeping

Any IU subject to pretreatment program reporting requirements is required to maintain records resulting from monitoring in a readily accessible manner for a minimum of 3 years (longer if during periods of any ongoing litigation). While the means for maintaining files is usually at the discretion of the POTW, all pretreatment activities should be documented and the documents maintained.

Types of IU records that the Control Authority should maintain ***include***:

Types of IU Records Retained

- Industrial waste questionnaire
- Permit applications, permits and fact sheets
- Inspection reports
- IU reports
- Monitoring data (including laboratory reports)
- Required plans (e.g., slug control, sludge management, pollution prevention)
- Enforcement activities
- **All** correspondence to and from the IU
- Phone logs and meeting summaries.

Types of POTW Records Retained

- Legal authority (e.g., SUO)
- Program procedures
- Program approval and modifications
- Copy of POTW NPDES permit(s)
- Local limits development
- ERP
- Correspondence to and from the EPA/State
- Annual reports to the Approval Authority
- Public notices
- Funding and resource changes
- Applicable Federal and State regulations
- IU compliance and permitting records

Tracking due dates, submissions, deficiencies, notifications, etc. and calculating effluent limitation noncompliance may be facilitated by a computerized data management system. Similarly, many Control Authorities use standardized forms (e.g., inspection questionnaires, chains-of-custody, field measurement records) and procedures (e.g., sampling, periodic compliance report reviews) to promote consistency and organization of program data.

In addition to specific IU records, Control Authorities should also maintain general program files that document specific program development and implementation activities that are not IU-specific. All information should be filed in an orderly manner and be readily accessible for inspection and copying by the EPA and State representatives or the public. The pretreatment regulations specify that all information submitted to the Control Authority or State must be available to the public without restriction, except for confidential business information.

Substantial Modifications of POTW *Figure 30*

Pretreatment Programs (40 CFR §403.18)

1. Modifications that relax POTW legal authorities (as described in 40 CFR §403.8(f)(1)), except for modifications that directly reflect a revision to 40 CFR Part 403, and are reported pursuant to 40 CFR §403.18(d) - Approval procedures for nonsubstantial modifications;
2. Modifications that relax local limits, except for modifications to local limits for pH and reallocations of the Maximum Allowable Industrial Loading of a pollutant that do not increase the total industrial loadings for a pollutant, which are reported pursuant to 40 CFR §403.18(d) - Approval procedures for nonsubstantial modifications;
3. Changes to POTW's control mechanism, as described in 40 CFR §403.(f)(1)(iii);
4. A decrease in the frequency of self-monitoring or reporting required of industrial users;
5. A decrease in the frequency of industrial user inspections or sampling by the POTW;
6. Changes to the POTW's confidentiality procedures; and
7. Other modifications designated as substantial modifications by the Approval Authority on the basis that the modification could have a significant impact on the operation of the POTW's Pretreatment Program; could result in an increase in pollutant loadings at the POTW; or could result in less stringent requirements being imposed on Industrial users of the POTW.

Public Participation and POTW Reporting

Section 101(e) of the CWA establishes public participation as one of its goals, in the development, revision, and enforcement of any regulation, standard, effluent limitation, plan, or program established by the EPA or any State. The General Pretreatment Regulations encourage public participation by requiring public notices and/or hearings for program approval, removal credits, program modifications, local limits development and modifications, and IUs in SNC.

POTW pretreatment program approval requests require the Approval Authority to publish a notice (including a notice for a public hearing) in a newspaper of general circulation within the jurisdiction served by the POTW. All comments regarding the request, as well as any request for a public hearing must be filed with the Approval Authority within the specified comment period, which generally last 30 days.

The Approval Authority is required to account for all comments received when deciding to approve or deny the submission. The decision is then provided to the POTW and other interested parties, published in the newspaper with all comments received available to the public for inspection and copying.

Once a local pretreatment program is approved, the Control Authority must implement that program as approved. Before there is a significant change in the operation of a POTW pretreatment program, a program modification must be initiated. For substantial program modifications (see Figure 30), the Control Authority is required to notify the Approval Authority of the desire to modify its program and the basis for the change. These changes become effective upon approval.

Approval Authorities (or POTWs) are required to give public notice of the request for a modification, but are not required to notify the public of the decision if no comments are received and the request is approved without changes. Nonsubstantial modifications must also be submitted to the Approval Authority for review and approval, but these changes do not require public notice.

And unlike substantial modifications, nonsubstantial modifications become effective 45 days after submission unless the Approval Authority notifies the POTW otherwise.

Annual Publication

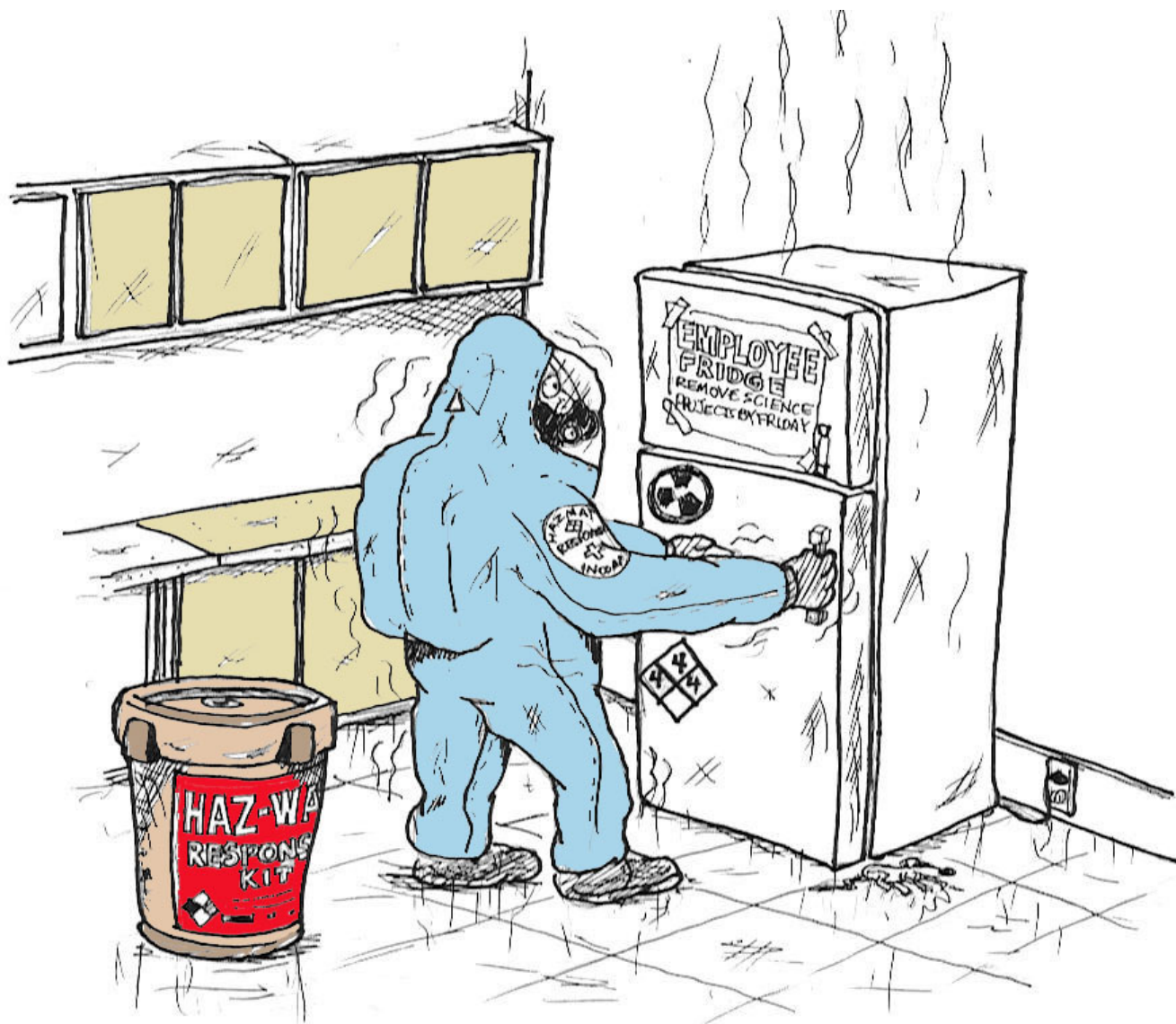
The POTW is also required to provide annual publication, in the largest daily newspaper in the municipality in which the POTW is located, of IUs that at any time during the previous twelve months were in SNC. In accordance with 40 CFR §403.12(I), Control Authorities are required to submit annual reports to the Approval Authority documenting program status and activities performed during the previous calendar year.

At a minimum, these reports must contain the following information:

1. A list of all POTW's IUs including names, addresses, pretreatment standards applicable to each user, IUs subject to categorical pretreatment standards or a brief explanation of deletions and a list of additions (with the aforementioned information) keyed to a previously submitted list;
2. A summary of the status of the IU compliance during the reporting period;
3. A summary of compliance and enforcement activities (including inspections) conducted by the POTW during the reporting period;
4. A summary of changes to the POTW's pretreatment program that have not been previously reported to the Approval Authority; and
5. Any other relevant information requested by the Approval Authority.

The first report is due within one year after program approval and at least annually thereafter. Approval Authorities may require additional information, or require that the reports be submitted in a specific format and/or at an increased frequency (e.g., semi-annually).





Never keep food or drinks in your sample refrigerator. I know all of you have done this in the past and I know you've seen someone work without gloves, but you need to be strong and remind personnel that you had enough of tasting all the nastiness. If you are new to this industry, don't fret, you will get a free taste very soon, one way or another. My advice, ask for the hepatitis injections and prepare for a case of the runs that will last for about 1-2 days, after this, you should be good to go. All of us have suffered through this ordeal.

What are the Symptoms of Viral Gastroenteritis?

The main symptoms of viral gastroenteritis are watery diarrhea and vomiting. The affected person may also have headache, fever, and abdominal cramps ("stomach ache"). In general, the symptoms begin 1 to 2 days following infection with a virus that causes gastroenteritis and may last for 1 to 10 days, depending on which virus causes the illness.

Guidance Manual For Implementing Total Toxic Organics (TTO)

Industrial User Pretreatment Program Responsibilities

Industrial Users (IUs) are required to comply with all applicable pretreatment standards and requirements. Demonstration of compliance requires certain IUs to submit reports, self-monitor, and maintain records. A summary of the reporting requirements are provided, with details of each of these requirements discussed below.

Reporting Requirements

Minimum Federal Pretreatment Program reporting requirements for IUs are specified in 40 CFR §403.12. Since Control Authorities are responsible for communicating applicable standards and requirements to IUs and for receiving and analyzing reports, it is essential for Control Authority personnel to understand IU reporting and notification requirements contained in the General Pretreatment Regulations. These requirements are summarized below.

Categorical Industrial User (CIU) Reporting Requirements

Baseline Monitoring Report (BMR) [40 CFR §403.12(b)]

Each existing IU that is subject to a categorical pretreatment standard (identified as a Categorical Industrial User, or CIU) is required to submit a BMR within 180 days after the effective date of the standard.

If a category determination has been requested, the BMR is not due until 180 days after a final administrative decision has been made concerning the industry's inclusion in the category. The BMR must contain the following information:

- Name and address of the facility and names of the operator and owners.
- List of all environmental control permits held by, or for, the facility.
- Description of operations, including the average rate of production, and applicable Standard Industrial.

SIC Codes

Classification (SIC) codes, schematic process diagrams, and points of discharge to the POTW from regulated processes:

- ✓ Flow measurements (average daily and maximum daily) for regulated process wastestreams and nonregulated wastestreams, where necessary.
- ✓ Pollutant measurements [daily maximum, average concentration, and mass (where applicable)] and applicable standards.
- ✓ Certification, by a qualified professional (reviewed by a representative of the CIU), of whether applicable pretreatment standards are being met and, if not, a description of the additional operation and maintenance (O&M) or pretreatment facilities that are needed to comply with the standards.

A schedule by which the IU will provide the additional O&M or pretreatment needed to comply with the applicable pretreatment standards.

BMRs

In addition to the certification noted above, BMRs must be signed and certified as detailed in 40 CFR §403.12(l) and as described later in this Chapter. If a CIU has already submitted the specific information required in a permit application or data disclosure form and this information is still current, it need not be reproduced and resubmitted in the BMR. The BMR is a one-time report, unless changed Federal categorical standards require submission of a new BMR.

At least 90 days prior to commencement of discharge, new sources are required to submit the above information (excluding the certification and compliance schedule), as well as information on the method that the source intends to use to meet the applicable pretreatment standards.

Compliance Schedule Progress Report [40 CFR §403.12(c)(3)]

A CIU that is not in compliance with applicable categorical standards by the time the standards are effective often will have to modify process operations and/or install end-of-pipe treatment to comply. Federal regulations require that the Control Authority develop and impose a compliance schedule for the CIU to install technology to meet applicable standards. As part of the BMR, a CIU that is unable to comply with the categorical standards must include a schedule for attaining compliance with the discharge standards.

In no case can the final or completion date in the schedule be later than the final compliance date specified in the categorical standards.

If deemed appropriate, the Control Authority may require compliance earlier than the final compliance date specified in the Federal regulations.

Compliance schedules are to contain increments of progress in the form of dates (not to exceed nine months per event) for commencement and completion of major actions leading to construction and operation of a pretreatment system and/or in-plant process modifications. Major activities could include hiring an engineer, completing preliminary analysis and evaluation, finalizing plans, executing a contract for major components, commencing construction, completion of construction, or testing operations.

In addition, the CIU must submit progress reports to the Control Authority no later than 14 days following each date in the compliance schedule (and final date for compliance), that include:

A statement of the CIU's status with respect to the compliance schedule

A statement of when the CIU expects to be back on schedule if it is falling behind, and the reason for the delay and steps being taken by the IU to return to the established schedule.

The Control Authority should review these reports as quickly as possible. When a CIU is falling behind schedule, the Control Authority should maintain close contact with the CIU. If the CIU fails to demonstrate good faith in meeting the schedule, the Control Authority may consider initiating appropriate enforcement action to correct the problem(s).

90-Day Compliance Reports [40 CFR §403.12(d) Section 403.12(d)] of the General Pretreatment Regulations requires a CIU to submit a final compliance report to the Control Authority.

An existing source must file a final compliance report within 90 days following the final compliance date specified in a categorical regulation or within 90 days of the compliance date specified by the Control Authority, whichever is earlier. A new source must file a compliance report to the POTW within 90 days from commencement of discharge.

These reports must contain:

Flow measurements (average daily and maximum daily) for regulated process wastestreams and nonregulated wastestreams, where necessary.

Pollutant measurements [daily maximum, average concentration, and mass (where applicable)] and applicable standards.

Certification, by a qualified professional, reviewed by a representative of the CIU, of whether pretreatment standards are being met and, if not, a description of the additional operation and maintenance (O&M) or pretreatment facilities that are needed to comply with the standards.

In addition to the certification noted above, 90-day final compliance reports must be signed and certified as detailed in 40 CFR §403.12(l) and as described later in this Chapter.

Figure 31. Definition of Upset (40 CFR §403.16)

Upset is defined as an exceptional incident in which there is unintentional and temporary noncompliance with categorical standards due to factors beyond the reasonable control of the CIU. An upset does not include noncompliance to the extent caused by operational error, improperly designed or inadequate treatment facilities, lack of preventative maintenance, or careless or improper operation.

CIUs are allowed an affirmative defense for noncompliance with categorical standards if they can demonstrate that the noncompliance was the result of an upset (Figure 31).

Conditions necessary to demonstrate an upset has occurred are detailed in 40 CFR §403.16 and require the CIU to submit at least an oral report to the Control Authority within 24 hours of becoming aware of the upset and containing the following information:

a description of the indirect discharge and the cause of the noncompliance
the date(s) and times of the noncompliance
steps being taken and/or planned to reduce, eliminate, and prevent reoccurrence of the noncompliance.

If this notification is provided orally, a written report must also be submitted within five days.

In any enforcement action, the IU has the burden of proof in establishing that an upset has occurred. The EPA is responsible for determining the technical validity of this claim.

Categorical and Significant Industrial User (SIU) Reporting Requirements

Periodic Compliance Reports [40 CFR §403.12 (e) & (h)]

After the final compliance date, CIUs are required to report, during the months of June and December, the self-monitoring results of their wastewater discharge(s).

The Control Authority must also require semi-annual reporting from SIUs not subject to categorical standards. The EPA established a minimum frequency of once every six months, determining this to be adequate for small SIUs or other facilities that have little potential to cause pass-through or interference or to contaminate the sewage sludge.

Periodic Compliance Reports

The EPA assumed that larger IUs and those that have more potential to cause problems would be required by the Control Authority to sample and report more often. All results for self-monitoring performed must be reported to the Control Authority, even if the IU is monitoring more frequently than required. Periodic compliance reports must include:

nature and concentration of pollutants limited by applicable categorical standards or required by the Control Authority.

flow data (average and maximum daily) as required by the Control Authority.

mass of pollutants discharged (applicable to CIUs where mass limits have been imposed).

production rates (applicable to CIUs where equivalent limits have been imposed or where limits imposed are expressed in allowable pollutant discharged per unit of production).

A Control Authority may choose to monitor IUs in lieu of the IU performing the self-monitoring. Additionally, 40 CFR §403.12(e) and (h) require compliance with 40 CFR Part 136 (Guidelines for Establishing Test Procedures for the Analysis of Pollutants).

To demonstrate compliance with these requirements, IUs may have to submit information regarding sample handling and analytical procedures to the Control Authority.

Development of standardized forms for use by IUs and their testing labs can facilitate documentation and submission of all required information and can streamline the IU and Control Authority review process.

Bypass [40 CFR §403.17] The General Pretreatment Regulations define “*bypass*” as the intentional diversion of wastestreams from any portion of a user’s treatment facility. If a bypass results in noncompliance, even if it was due to essential maintenance, the IU must provide a report to the Control Authority detailing a description of the bypass and the cause, the duration of the bypass, and the steps being taken and/or planned to reduce, eliminate, and prevent reoccurrence of the bypass.

Oral notice must be provided to the Control Authority within 24 hours of the detection of an unanticipated bypass, with a written follow-up due within 5 days. For an anticipated bypass, the IU must submit notice to the Control Authority, preferably 10 days prior to the intent to bypass.

Notification of Potential Problems [40 CFR §403.12(f)]

All IUs are required to notify the Control Authority immediately of any discharges which may cause potential problems. These discharges include spills, slug loads, or any other discharge which may cause a potential problem to the POTW.

Noncompliance Notification [40 CFR §403.12(g)(2)]

If monitoring performed by an IU indicates noncompliance, the IU is required to notify the Control Authority within 24 hours of becoming aware of the violation. In addition, the IU must repeat sampling and analysis, and report results of the re-sampling within 30 days.

The repeat sampling is not required if the Control Authority samples the IU at least once per month or if the Control Authority samples the IU between the time of the original sample and the time the results of the sampling are received.

Notification of Changed Discharge [40 CFR §403.12(j)]

All IUs are required to promptly notify the Control Authority in advance of any substantial changes in the volume or character of pollutants in their discharge.

Notification of Discharge of Hazardous Wastes [40 CFR §403.12(p)]

IUs discharging more than 15 kilograms per month of a waste, which if otherwise disposed of, would be a hazardous waste pursuant to the RCRA requirements under 40 CFR Part 261 are required to provide a one-time written notification of such discharge to the Control Authority, State, and the EPA.

IUs discharging any amount of waste, which if disposed of otherwise, would be an acutely hazardous waste pursuant to RCRA must also provide this notification. This written notification must contain the EPA hazardous waste number and the type of discharge (i.e., batch, continuous).

If the IU discharges more than 100 kilograms per month of the hazardous waste, the written notification must also include:

An identification of the hazardous constituent in the IU's discharge,

An estimate of the mass and concentration of the constituents in the IU's discharge, and

An estimate of the mass and concentration of constituents in the IU's discharge in a year.

IUs must also provide a certification accompanying this notification that a waste reduction program is in place to reduce the volume and toxicity of hazardous wastes to the greatest degree economically practical.

Within 90 days of the effective date of the listing of any additional hazardous wastes pursuant to RCRA, IUs must provide a notification of the discharge of such wastes.

Signatory and Certification Requirements [40 CFR §403.12(l)]

Pursuant to 40 CFR §403.12(l), BMRs, 90-day compliance reports and periodic compliance reports from CIUs must be signed by an authorized representative of the facility and contain a certification statement attesting to the integrity of the information reported. The reports should be signed by one of the following:

A responsible corporate officer if the IU is a corporation.

A general partner or proprietor if the IU is a partnership or sole proprietorship.

A duly authorized representative of the above specified persons if such authorization is in writing, submitted to the Control Authority and specifies a person or position having overall responsibility for the facility where the discharge originates or having overall responsibility of environmental matters for the facility.

As required in 40 CFR §403.6(a)(2)(ii), the certification statement must read as follows:

"I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete.

I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations."

While Federal regulations only require Control Authorities to require these signatures and certifications from CIUs, many POTWs have found it important to impose these requirements for all IU reports. To facilitate compliance, many Control Authorities have developed forms that include the certification statement and signatory requirements for use by all IUs.



Is entry necessary? Can the task be accomplished from the outside? For example, measures that eliminate the need for employees to enter confined spaces should be carefully evaluated and implemented if at all possible before considering human entry into confined spaces to perform non-emergency tasks.

Self-Monitoring Requirements

All SIUs, including CIUs must conduct self-monitoring as part of several different reporting requirements as noted above. For CIUs, this includes the BMR, 90-day compliance report and periodic compliance reports (40 CFR §§403.12(b),(d), and (e), respectively). Non-categorical SIUs are required to self-monitor as part of the periodic reporting requirements (40 CFR §403.12(h)). As noted in 40 CFR §§403.12(g)(4), sample collection and analysis for all required pretreatment program reports must be conducted using 40 CFR Part 136 procedures and amendments thereto.

Refer to Chapter 4 of this manual and the EPA's 1994 *Industrial User Inspection and Sampling Manual for POTWs* for additional information on sample collection and analysis procedures.

Based on the specific pollutants regulated by categorical standards, different types of samples may have to be collected. For BMR and 90-day compliance reports, a minimum of four grab samples must be collected for pH, cyanide, total phenols, oil and grease, sulfide, and volatile organics.

If these pollutants are not regulated by the specific categorical standard, monitoring is not required. Twenty-four hour flow-proportional composite samples must be collected for all other pollutants. The Control Authority may waive flow-proportional composite sampling if an IU demonstrates that flow-proportional is not feasible. In these cases, time-proportional composite samples may be collected.

Self-monitoring for periodic compliance reports must be conducted in accordance with the IU's discharge permit requirements. The Control Authority must ensure that these permits specify sampling location(s), required sampling frequencies, sample types to be collected, sampling and analytical procedures (40 CFR Part 136), and associated reporting requirements. At a minimum, CIUs must monitor for all categorically regulated pollutants at least once every six months, although permits issued by the local Control Authority may require more frequent monitoring.

TTO

In certain instances, CIUs subject to TTO standards may implement alternatives in lieu of monitoring all regulated toxic organic compounds.

TOMP

For example, the electroplating and metal finishing standards allow IUs to monitor only for those toxic organic compounds that are reasonably expected to be present. Additional TTO guidance related to the electroplating and metal finishing categories can be found in the EPA's 1984 *Guidance Manual for Electroplating and Metal Finishing Pretreatment Standards*.

For certain industries (i.e., electroplating, metal finishing, and electrical and electronic components) Control Authorities have the option of allowing the CIU to prepare and implement a Toxic Organic Management Plan (**TOMP**) in lieu of periodic monitoring.

In those instances, the TOMP should identify all potential sources from which toxic organic materials could enter the wastestream and propose control measures to eliminate the possibility. Where a TOMP is allowed, an IU can demonstrate compliance through adherence to the TOMP and submission of periodic certification statements attesting to the fact that: *"no dumping of concentrated toxic organic pollutants has occurred and that the facility's TOMP is being implemented."*

TOMPs cannot be used in lieu of monitoring for BMRs and 90-day compliance reporting requirements. The categorical standards for some industries (i.e., aluminum forming, copper forming, coil coating, and metal molding and casting) allow IUs to monitor oil and grease (**O&G**) as an alternative to TTO monitoring.

This option may be used to fulfill TTO monitoring requirements of the BMR, 90-day compliance report, and periodic compliance reports and allows the IU to determine whether it wants to demonstrate compliance with the TTO or the O&G standards. A detailed description of TTO monitoring requirements is provided in the EPA's 1985 *Guidance Manual for Implementing Total Toxic Organics (TTO) Pretreatment Standards*.

Recordkeeping Requirements

IUs are required to maintain records of their monitoring activities [40 CFR §403.12(O)]. Information, at a minimum, shall include the following:

- sampling methods, dates and times,
- identity of the person(s) collecting the samples and of the sampling location(s),
- the dates the analyses were performed and the methods used,
- the identity of the person(s) performing the analyses and the results of the analyses.

These records shall be retained for at least 3 years, or longer in cases where there is pending litigation involving the Control Authority or IU, or when requested by the Approval Authority.

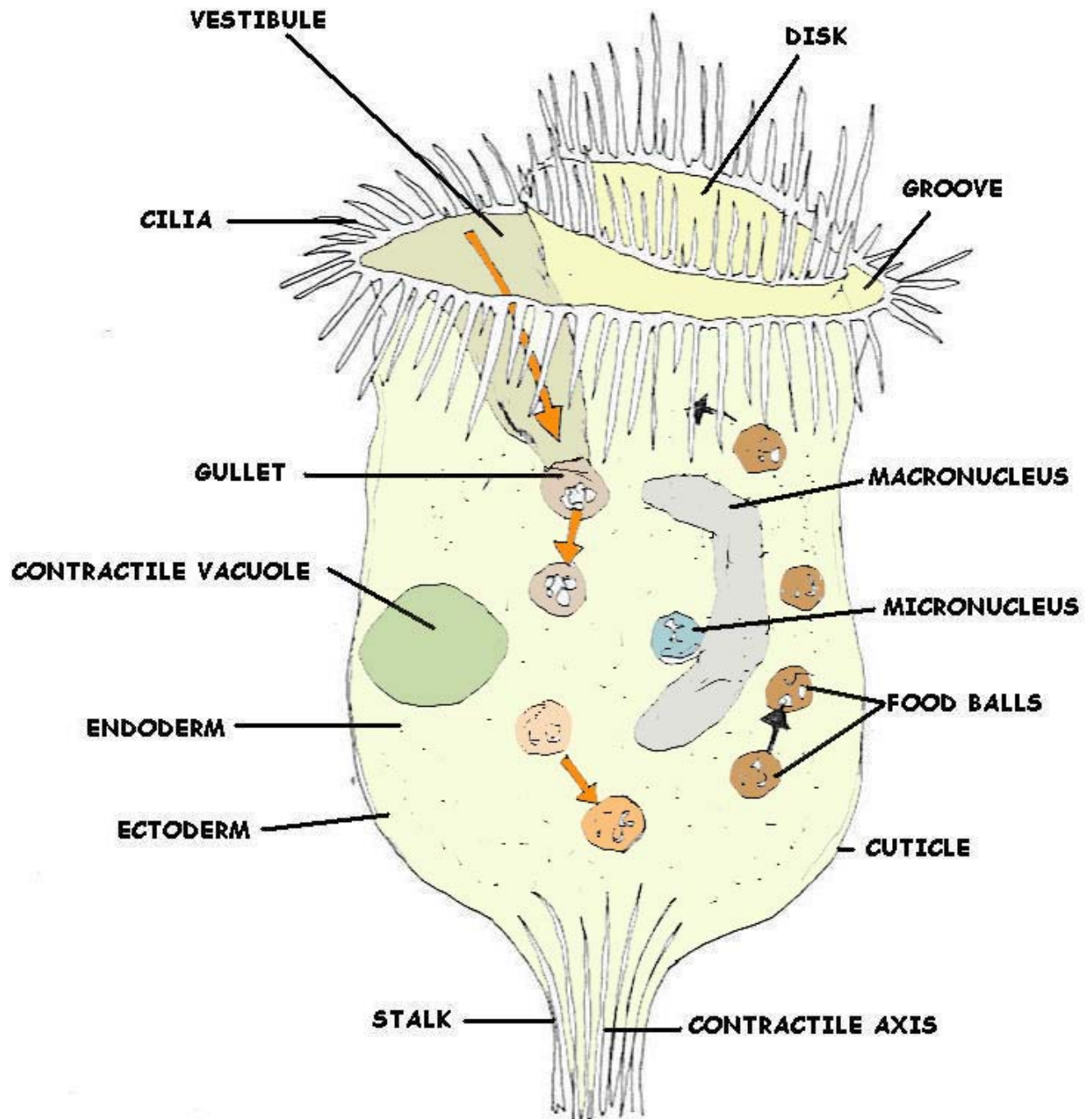
These records must be available to the Control Authority and Approval Authority for review and copying. Historically, most Control Authorities do not dispose of any records; rather, older records are archived at an off-site location.



Database personnel are essential to the pretreatment data management operation.

Figure 32. Industrial User Reporting Requirements

REQUIRED REPORT AND CITATION	APPLY TO	REPORT DUE DATE	PURPOSE OF REPORT
Baseline Monitoring Report (BMR) 40 CFR §403.12(b)(1-7)	CIUs	Existing Source - Within 180 days of effective date of the regulation or an administrative decision on category determination. New Source - At least 90 days prior to commencement of discharge.	- To provide baseline information on industrial facility to Control Authority - To determine wastewater discharge sampling points - To determine compliance status with categorical pretreatment standards
Compliance Schedule Progress Reports 40 CFR §403.12(c)(1-3)	All IUs	Within 14 days of each milestone date on the compliance schedule; at least every 9 months.	- To track progress of the industrial facility through the duration of a compliance schedule.
90-Day Compliance Report 40 CFR §403.12(d)	CIUs	Within 90 days of the date for final compliance with applicable categorical pretreatment standard; for new sources, the compliance report is due within 90 days following commencement of wastewater discharge to the POTW.	- To notify Control Authority as to whether compliance with the applicable categorical pretreatment standards has been achieved - If facility is noncompliant, to specify how compliance will be achieved.
Periodic Compliance Report 40 CFR §403.12(e)	CIUs	Every June and December after the final compliance date (or after commencement of a discharge for new sources) unless frequency is increased by the Control Authority.	- To provide the Control Authority with current information on the discharge of pollutants to the POTW from categorical industries.
Notice of Potential Problems 40 CFR §403.12(f)	All IUs	Notification of POTW immediately after occurrence of slug load, or any other discharge that may cause problems to the POTW.	- To alert the POTW to the potential hazards of the discharge.
Noncompliance Notification 40 CFR §403.12(g)(2)	All IUs	Notification of POTW within 24 hours of becoming aware of violation.	- To alert the POTW of a known violation and potential problems which may occur.
Periodic Compliance Reports for Noncategorical Users 40 CFR §403.12(h)	Non-Cat. SIUs	Every six months on dates specified by the Control Authority.	- To provide the POTW with current information on the discharge of pollutants to the POTW from industrial users not regulated by categorical standards.
Notification of Changed Discharge 40 CFR §403.12(j)	All IUs	In advance of any substantial changes in the volume or character of pollutants in the discharge.	- To notify POTW of anticipated changes in wastewater characteristics and flow which may affect the POTW.
Notification of Hazardous Wastes Discharge 40 CFR §403.12(p)	All IUs	For new discharges, within 180 days after commencement of discharge.	- To notify POTW, EPA, and State of discharges of hazardous wastes under 40 CFR Part 261.
Upset 40 CFR §403.16	CIUs	24 hours of becoming aware of the upset (5 days where notification was provided orally)	- To notify the POTW of unintentional and temporary noncompliance with categorical standards.
Bypass 40 CFR §403.17	All IUs	10 days prior to date of the bypass or oral notice within 24 hours of the IU becoming aware of the bypass with written notification within 5 days.	- To notify the POTW of noncompliance and potential problems which may occur



VORTICELLA

(TYPE OF PROTOZOAN FOUND IN STAGNANT WATER)

Examples of Enforcement and Regulatory Letters

Contact Person

Company Name

Company Address

City, State, Zip

Certified Mail

Return Receipt Requested

OR

Hand Delivered

Rec'd by _____ **Date** _____
Company Name

NOTICE OF VIOLATION

RE: Reporting

Wastewater Discharge Permit# _____ issued to _____
Permit issue No. Company Name

requires _____ to submit _____
Company Name Type of Report

reports to the City of Sunflower _____
Qualification of Report

The report submitted by _____ on _____
Individual or Company Name Date Received by E &

for _____ was due on _____, _____
Description or Violation Date Number

days late. _____ is therefore in violation with its permit.
Company Name

_____ is required to submit to the Enforcement
Company Name

and Monitoring Section a written report outlining the reason(s) for failure to meet this

requirement and detailing the corrective action(s) taken to prevent future violations.

This receipt must be received by _____

Mailing date + 15 Days (ESTABLISHED BY SECRETARY)

Failure to comply with the requirements of this letter will subject _____
Company Name

to further enforcement action(s). This Notice does not preclude the City from taking additional

enforcement action(s) under Chapter 10 of the Sunflower City Code.

Should you have any questions regarding this Notice, please contact Water Quality Division at 474-8888. Our office hours are 7:00 a.m. to 3:30 p.m., Monday through Friday.

Sincerely,

Name of Inspector

Title

Department

Date

Representative

Company

Address

City, State, Zip

Dear _____:
Representative

Re: **NOTICE OF VIOLATION NO.** _____
Nov No. Assigned

Thank you for submitting the _____
Analysis, Report

required by the Notice of Violation (**NOV**) dated _____,
Date

covering the _____ violations (s).
Parameter (s)

_____ has met all the requirements of
Company
this Notice of Violation and no further action is required at this time. This letter does not preclude the City from taking additional enforcement action(s) under Chapter 10 of the Sunflower City Code.

Should you have any questions regarding this letter, please contact the Water Quality Division at 474-8888. Our office hours are 7:30 a.m. to 3:30p.m. Monday through Friday.

Sincerely,

Inspector

Title

NOTICE TO SHOW CAUSE

_____ has been previously notified of _____ violations. In light of the pretreatment violations identified in the attached Notice(s) and in this Notice to Show Cause, the City of Sunflower, acting as the Control Authority pursuant to the legal authority established by Title 40, Code of Federal Regulations, Part 403, and in accordance with Chapter 10 of the Sunflower City Code, hereby notifies

_____ of its intent to utilize all appropriate remedies to address these pretreatment violations. These remedies include monetary penalties.

Representatives from _____ are required to attend a Meeting to Show Cause to be held at:

Place: Water Quality Conference Room
POTW Waste Water Treatment Plant
8111 W. Montebello
Sunflower, AZ 85296

Date: _____, _____

Time: _____

During the Show Cause meeting, _____ will be given the opportunity to respond to the allegations stated below and will be asked to show cause why the City should not seek monetary and / or other penalties in response to the following:

During the time period referred to above,

_____ discharged in violation of its permit on at least _____ occasion(s).

A _____ report was submitted _____ days late.

A 24 Hour Notification was _____ days late.

It is hereby requested that _____ have in Attendance at this meeting persons knowledgeable about the matters alleged in this Notice as well as persons having decision making authority. Your representatives may be accompanied by legal counsel if you so desire.

A representative from the City Attorney's office may be present at the meeting. Any written response to this Notice that you would like us to consider must be in my office on or before _____.

We would appreciate if you would let us know by _____.

A copy of the latest edition of the City's Civil Penalty Policy together with the Civil Penalty Calculation Worksheet is enclosed.

Your failure to appear will mean that the City of Sunflower will take all appropriate enforcement action it deems necessary based on the facts as outlined in this notice and attachments.

Should you have any questions regarding this notice, please contact Water Quality Division at 474-8888. Our office hours are 7:00 a.m. to 3:30 p.m., Monday through Friday.

Sincerely,

Chris Binder,
Water Quality Supervisor

Company

Certified Mail

Hand delivered

NOTICE OF VIOLATION

RE: Permit Conditions

A review and evaluation of _____'s _____

Report that was received on _____, indicates that

your monthly analysis for _____ was not included. The monthly analysis is required as indicated on your Wastewater Discharge Permit # _____, and also aids the City of Sunflower in determining compliance with the discharge standards.

_____ is therefore required to immediately

sample for _____ and submit the analysis by _____.

You are also required to submit a written report outlining the reason(s) for failure to meet this requirement and the corrective action(s) taken to prevent future violations.

This written report must be submitted by _____.

Failure to comply with the requirements of this letter will subject _____ to further enforcement action(s). This notice does not preclude the City from taking additional enforcement action(s) under Chapter 10 of the Sunflower City Code.

Should you have any questions regarding this notice, please contact Water Quality Division at 474-8888. Our office hours are 7:00 a.m. to 3:30 p.m., Monday through Friday.

Inspector

Contact Person

Company Name

Company Address

City, State, Zip

Certified Mail

Return Receipt Requested

OR

Hand Delivered

Rec'd by _____ Date _____
Company Name

NOTICE OF VIOLATION
RE: Effluent Limits (City Monitoring)

The discharge to sewer from _____ exceeded the maximum
Company Name
Allowable limit for _____ as established in your Wastewater Discharge
Effluent
Permit No. _____

<u>Date</u>	<u>Parameter</u>	<u>Discharge Concentration</u>	<u>Discharge Limit</u>
-------------	------------------	--------------------------------	------------------------

_____ is required to submit to the Enforcement and Monitoring
Company Name
section a detailed written report outlining the reason(s) the violation(s) occurred and the corrective action taken to prevent future violations. This report (must be/was) (submitted/received) (by/on)

Mailing Date + 15 Days (ESTABLISHED BY SECRETARY)

Failure to comply with the requirements of this letter will subject _____
Company Name
to further enforcement action(s).

This Notice does not preclude the City from taking additional enforcement action(s) under Chapter 10 of the Sunflower City Code.

Should you have any questions regarding this notice, please contact Water Quality Division at 474-8888.

Our office hours are 7:30 a.m. to 3:00 p.m., Monday through Friday.

Name of Inspector

Title

Company

Re: Wastewater Discharge Permit Renewal

Dear:

A review of _____'s industrial waste
file indicates that your Wastewater Discharge Permit # _____,
for your _____ facility expires_____

In order for a valid permit to be issued, the enclosed Industrial Waste Permit Application
must be properly filled out and returned to our office by_____.

Should you have any questions regarding these results, please contact Water Quality Division at 474-
8888. Our office hours are 7:00a.m. to 3:30p.m., Monday through Friday.

Signature

Permit Appeals Process Example

(Section 7-88- Chapter 10, Sunflower City Code)

Any Permit applicant or Permittee (aggrieved party) may petition the Director to reconsider the conditions and limitations of a Permit issued or amended under the authority of Section 28-46(a) of the Sunflower City code by filing a petition for review with the Director within twenty (20) days of receipt of the Permit.

Failure to submit a timely petition for review shall be deemed to be a waiver of the administrative appeal.

In its petition, the aggrieved party must identify the Permit provisions objected to, specify in detail the reasons for objection, and present the alternative condition, if any, it seeks to place in the Permit.

The provisions of the Permit that are not objected to shall not be stayed pending the appeal.

If the Director fails to act within 30 days from receipt of the petition, it shall be deemed to be denied. Decisions not to reconsider the issued or amended Permit, not to issue a Permit, or not to amend a Permit shall be considered final administrative actions for purposes of judicial review.

The aggrieved party seeking judicial review of the final Permit decision may file a complaint with the Superior Court for Gila County, Arizona.

The petition for review should be addressed to:

Bill Walker, Superintendent
City of Sunflower
Pollution Control Division
8111 W. Montebello Ave

Sunflower, Arizona 85629

Zero Discharge Examples

November 13, 2012

Mr. Mike Ploughe
Plant Superintendent
Ploughe Products
8111 West Montebello Lane
Sunflower, Arizona 85027

RE: Class B Zero Process Discharge Permit inspection conducted by the City of Sunflower Pollution Control Division on July 12, 2015.

Dear Mr. Ploughe:

As per our phone conversation of July 18, 2015, the purpose of this letter is to clarify the findings listed in the inspection report, dated July 12, 2015. In the description of findings section of the inspection report, it was noted that "All hazardous wastes are shipped off site for disposal."

During the inspection it was noted that hazardous waste were in fact shipped off site for disposal from the former Ploughe Products (PP) location at 3632 West Heidi, Sunflower, Arizona. It was also noted that since PP relocated to 8111 West Montebello Lane, Sunflower, Arizona, no hazardous waste have been shipped off site for any reason.

Please be aware that your facility may be subject to solid or hazardous waste management requirements pursuant to the Federal Resource Conservation and Recovery Act (PL 94-580 as amended) and state hazardous waste management regulations.

The attached general material describes federal requirements for hazardous waste generators and transporters. This packet includes descriptions of hazardous waste management requirements, which may apply to your operation if it involves generating or transporting hazardous waste.

In order to insure that your operation comply with federal, state, and local hazardous waste management regulations, please review the enclosed material and consult the following agencies to determine all specific requirements that apply to your operation:

U.S. EPA
RCRA/Superfund
Washington, D.C.
Information Hotline
(800) 424-9346

Mr. Patrick Kuefler
Arizona Dept. of Environmental Quality
Hazardous Waste Compliance
3033 North Central Ave
Sunflower, AZ 85012
(602) 207-4105

Should you have any questions, please contact me at 474-8888. Our office hours are 8:00 a.m. to 5:00 p.m., Monday through Friday.

Sincerely,

Bill Fields
Water Quality Inspector

Ms. Melissa Durbin
Environmental/ Safety Manager
ACME Corporation
556 North 39th Avenue
Sunflower, Arizona 85093

July 10, 2021

RE: WARNER POWDER COATING FACILITY INSPECTION
556 N. 39TH AVENUE, SUNFLOWER, AZ. 85093

ACME CORPORATION FACILITY INSPECTION
4325 W. MONROE AVENUE, SUNFLOWER, AZ 85093

Dear Ms. Davis:

Thank you again for your time and cooperation during inspection of the above-referenced facilities conducted by the City of Sunflower Pollution Control Division (PCD) on June 1, 2021. Inspection reports are attached for your information.

Based on the inspection findings and review of previously submitted Industrial Wastewater Permit Applications for both Warner Coatings and Acme Corporation (dated October 11, 2001 and January 30, 2021, respectively), PCD has determined that:

1) Warner Technical and Acme Corporation are subject to Categorical Standards for Metal Finishing, pursuant to Title 40 Code of Federal Regulations Part 433 (Metal Finishing Point Source Category, copy attached);

2) Pursuant to Sunflower City Code Chapter 28 Article VI (Industrial User and Pretreatment Requirements, copy attached), Warner Technical and Acme Corporation must obtain a Class B Zero Process Discharge Permit and a Zero Categorical Process Discharge Permit, respectively; to discharge existing process and non-process wastewater to the City sanitary sewer system.

Presently, PCD is processing a Class B Zero Categorical Process Discharge Permit for each facility. As you requested during the inspections, all future correspondence regarding Warner Technical Coatings or Acme Corporation will be directed to Able Lopez (Warner Technical Coatings Production Manager) and Willie Clinton (Acme Corporation Manufacturing Coordinator), respectively.

Should you have any questions, please contact me at 534-3681. Our office hours are 8:00 a.m. to 5:00 p.m., Monday through Friday.

Sincerely,

Bill Fields
Senior Water Quality Inspector

Chapter 6 Hauled Wastes

Definition of Domestic Septage

Domestic septage is defined as either the liquid or solid material removed from a septic tank, cesspool, portable toilet, Type III marine sanitation device, or similar treatment works that holds only domestic sewage.

Domestic septage does not include liquid or solid material removed from these systems that receives either commercial wastewater or industrial wastewater and does not include grease removed from a restaurant grease trap. [40 CFR Part 503.9(f)]

In addition to receiving wastes through the collection system, many POTWs accept trucked wastes, and in a few instances, wastes received via train. As specified in 40 CFR §403.1(b)(1), pollutants from non-domestic sources which are transported to the POTW by truck or rail are also subject to the General Pretreatment Regulations.

Hauled wastes, like wastes received through the collection system, have the potential to impact the POTW, making regulatory control of these wastes necessary. Recent studies have shown an increasing frequency of uncontrolled discharges to POTWs from waste haulers.



Because of their unique nature, waste haulers are not regulated in the same way as other types of IUs. Since no specific Federal regulatory controls exist, some POTWs have developed hauled waste control programs. For more information on hauled waste, refer to the EPA's 1998 *Guidance Manual for the Control of Waste Hauled to Publicly Owned Treatment Works*.



Plastic containment protection under oil tanker truck.

Nature of Hauled Wastes

Wastes are hauled to POTWs for several reasons. By far, the majority of hauled waste is domestic septage. Since these wastes are domestic in nature, treatment at a POTW is the most appropriate disposal method. Other types of wastes are also regularly hauled to POTWs for a variety of reasons, such as:

- the facility is located outside the jurisdictional boundaries of the POTW (e.g., located in rural areas) and is not connected to the collection system,
- the wastes may be known to cause collection system problems, but can be treated at the POTW (e.g., grease trap cleanout wastes),
- the facility is connected to the sewer but does not have the capacity to discharge the volume of waste generated (e.g., groundwater remediation activities at an IU),
- a POTW rejects acceptance of a waste from an IU forcing the IU to haul the waste to a different POTW that agrees to accept the waste.

Common to all these wastes is the fact that the POTW does not know for certain the nature and concentration of these wastes, as hauled, without implementing some type of control or surveillance program.

Control Programs

Section 403.5(b)(8) of the General Pretreatment Regulations specifically prohibits the introduction of any trucked or hauled pollutants to the POTW, except at discharge points designated by the POTW. This is the only pretreatment requirement specifically addressing hauled wastes. However, many POTWs have determined that additional controls are necessary to further limit these discharges and to prevent adverse impacts from these discharges.

These control programs include practices such as permitting, sampling, manifesting, surveillance, and other forms of hauler documentation. In many instances, these control programs have shifted the hauling of waste from one POTW to other POTWs that are not implementing such a program.

Most often, it is the smaller POTWs that do not have hauler control programs, including many POTWs that are not even required to implement Pretreatment Programs. The effect of this change from larger to smaller POTWs and from more to less control is that there has been an increase in negative impacts to POTWs and receiving streams.

Two apparent options for addressing this concern are for: (1) the smaller and non-pretreatment POTWs to initiate waste hauler control programs; or (2) the larger POTWs to institute sound control programs that will adequately regulate these wastes yet not drive these haulers to search for other less sound disposal alternatives.

POTW waste hauler control programs should address the following six elements:

Impact to POTW - Prior to acceptance of a new waste from a hauler, the POTW needs to evaluate the potential impacts to the POTW from this waste. POTWs may require haulers or generators of hauled waste to perform a treatability study to demonstrate the effectiveness of treatment on this waste. POTWs must evaluate the impacts of this waste when evaluating the adequacy of local limits as well as when developing or revising local limits.

Permitting - A permit is the most direct and efficient method of regulating waste haulers. Permits provide the opportunity to monitor and regulate haulers based on the nature of the hauled waste and the potential impacts of that waste on the POTW. Unique permit conditions may include: right of refusal, daily flow limitations, discharge time limitations, and manifesting requirements.

Discharge Point - As specified in the General Pretreatment Regulations, hauled waste can only be discharged at points designated by the POTW. This option is to provide the POTW with the ability to control and observe these discharges at specified locations, thereby minimizing the potential for adverse impacts.

Monitoring - The POTW should institute a monitoring program to evaluate the nature and concentration of discharges. Both POTW monitoring and hauler self-monitoring may be appropriate. Many POTWs require that all loads of hauled waste must be sampled, but analyses are only performed on a predetermined percentage of these wastes or when problems occur.

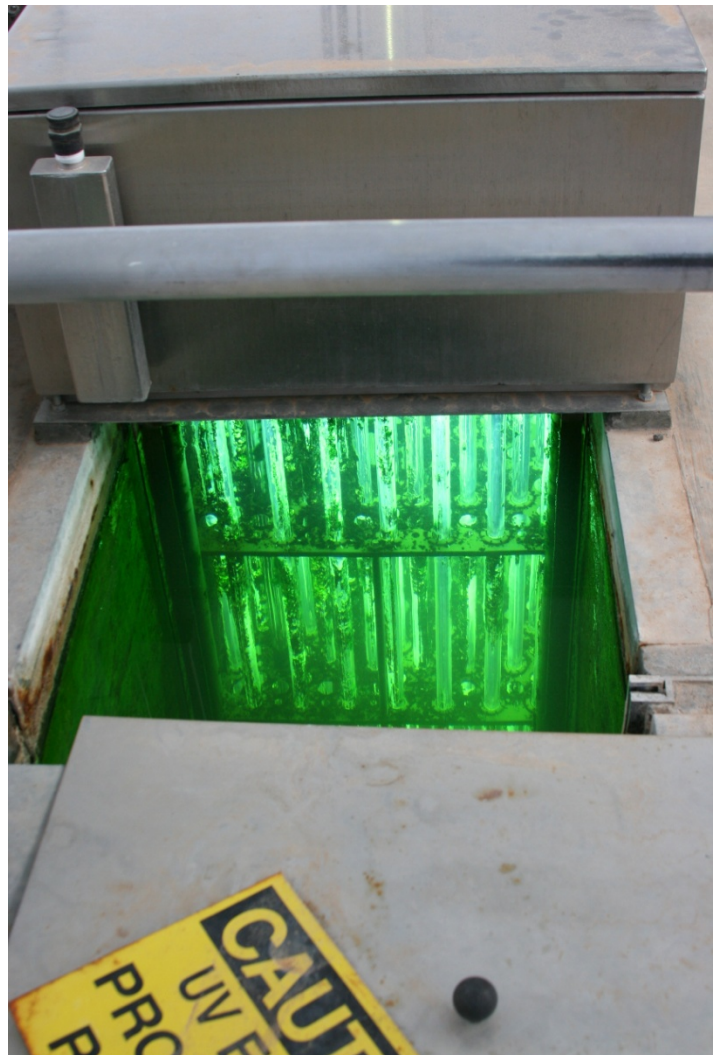
Unanalyzed samples are refrigerated and kept for several weeks or months until the POTW is certain that the waste has not impacted the POTW. The frequency of sampling may also be dependent on the variability of the waste. Each load from a hauler that delivers highly variable loads may have to be sampled and analyzed; whereas, a much smaller percentage may be appropriate for more consistent waste types. As noted earlier, all Federal, State, and local discharge limitations apply to these wastes. The POTW may also consider inspecting the waste generators to confirm the source of these wastes.

Hauler Documentation - The POTW should require waste haulers to document the source of wastes being discharged, potentially including manifests. Manifests should include general hauler information, information on the waste generator (e.g., name, address, and phone number), the type of wastes collected, volumes, known or suspected pollutants, and certification that the load is not a hazardous waste. A useful technique is to contact the waste generators to verify the information on the manifest.

Legal Authority - If not already in place, the POTW's local ordinance (and approved pretreatment program) should be modified to add language specifying all of the controls that are applicable to waste haulers. This will ensure that waste haulers and POTW personnel will know the procedures, expectations, liabilities, etc. associated with the control program.

In addition to the specific controls described above, POTWs should implement procedures to identify and eliminate illegal discharges. Procedures may include periodic sewer line sampling, surveillance of suspected illegal discharge points, education of industries regarding hauled waste, increased enforcement, and public awareness of illegal dumping.

UV Train



Hauled Waste Concerns

Every hauled waste discharge has the potential to impact the POTW. Unlike discharges from IUs connected to the POTW, the makeup of a load of hauled waste is virtually unknown without some type of monitoring, be it visual or analytical. Even loads of domestic septage can cause problems at a POTW. The majority of waste haulers are reputable business people who provide a valuable service to the public and industry; however, the unique attributes of hauled waste can be devastating when unethical haulers dump incompatible wastes at POTWs.

Domestic septage can be partially digested, higher in metals concentrations than normal domestic wastes, or contain small amounts of household contaminants (e.g., cleaners). Similarly, disinfectants used in portable toilets have the potential to impact POTW operations. Receipt of hauled hazardous waste (as defined in the Resource Conservation and Recovery Act (**RCRA**)) may not only impact POTW operations, but subject the POTW to additional reporting requirements. The Domestic Sewage Exclusion, specified in 40 CFR §261.4 (a)(1)(ii), provides that hazardous wastes mixed with domestic sewage are exempt from the RCRA waste regulations.

However, hazardous wastes received by truck or rail (or dedicated pipe) are not exempt from the regulations. POTWs that accept hazardous wastes from these sources are granted “**permit by rule**” status under RCRA (40 CFR §270.60(c)) provided that certain requirements are met. The two most significant conditions are that the POTW must be in compliance with all of its NPDES permit requirements and the waste must comply with all Federal, State, and local pretreatment requirements. Nationwide, very few POTWs are knowingly accepting hauled hazardous waste.

POTWs should be aware that hauled process wastes from facilities subject to Federal categorical pretreatment standards are still subject to those standards. This condition highlights the need for POTWs to have a clear understanding of the source of the waste since applicable standards may be based on the origin of that waste.

Another potential problematic waste is that from remedial site clean-up operations. Groundwater contaminated with gasoline or diesel fuel is by far the most common type of waste from these operations. While these wastes may contain flammable and toxic compounds (e.g., benzene and toluene), another concern is that large volumes of this waste at a small POTW may actually “**flush**” the treatment plant, thereby interfering with treatment operations. Similar concerns also exist for landfill leachate, another commonly hauled wastestream. Remedial wastes may also come from Comprehensive Environmental Response, Compensation, and Liability Act (**CERCLA**) sites, also known as Superfund sites. For CERCLA guidance, refer to the EPA’s 1990 *CERCLA Site Discharges to POTWs Guidance Manual*.

Other concerns for POTWs that accept hauled wastes include:

Illegal dischargers may be discharging toxic pollutants that can pass through or interfere with the POTW operations;

Grease trap wastes can coat and inhibit POTW treatment operations;

Local limits may not account for pollutants in hauled wastes;

Hauled wastes may contain pollutants for which local limits do not exist; thus, the impacts of this waste are not readily identifiable;

Hauled wastes may be unmixed and/or highly concentrated.

For further information on the acceptance of hazardous waste at POTWs, refer to the *Guidance Manual for the Identification of Hazardous Wastes Delivered to Publicly Owned Treatment Works by Truck, Rail, or Dedicated Pipe*.

Chapter 7 Pollution Prevention

As the nation's environmental laws and regulations have developed over the past three decades, a new paradigm has shifted the approach to waste management. Initially, the EPA focused on managing the pollution generated through treatment and disposal in an environmentally safe manner. However, we have learned that conventional treatment and disposal can transfer pollutants from one medium to another with no net reduction. In striving to meet new and often more stringent environmental laws, industries have found ways to reduce or prevent pollution at the source.

Recognizing that source reduction is more desirable than treatment and disposal, the EPA now emphasizes preventing or eliminating the generation of waste. The Pollution Prevention Act of 1990 (**PPA**) established pollution prevention (referred to as "**P2**") as a national objective.

Pollution Prevention Act PPA

Pollution prevention is indirectly defined in the **PPA** as source reduction. Source reduction is any practice that reduces or eliminates the creation of pollutants. Thus, the amount of any hazardous substance, pollutant, or contaminant entering any waste stream or otherwise released into the environment (including fugitive emissions) is reduced prior to recycling, treatment, or disposal. Source reduction can be achieved through equipment or technology modifications, process or procedural modifications, reformulation or redesign of products, substitution of raw materials, or improvements in housekeeping, maintenance, training, or inventory control.

The PPA established a pollution prevention hierarchy as national policy, declaring that:

Pollution should be prevented or reduced at the source.

Pollution that cannot be prevented should be recycled in an environmentally safe manner.

Pollution that cannot be prevented or recycled should be treated in an environmentally safe manner.

Disposal or other release into the environment should be employed only as a last resort and should be conducted in an environmentally safe manner.

Thus, under the Pollution Prevention Act, recycling, energy recovery, treatment, and disposal are not included within the definition of pollution prevention. However, some practices commonly described as "**in-process recycling**" may qualify as pollution prevention. Although recycling is not pollution prevention, as indicated in the hierarchy, it is the next desirable practice where pollution cannot be prevented or reduced.

Recycling conducted in an environmentally sound manner shares many of the advantages of prevention, for it can reduce the need for treatment or disposal and conserve energy and resources.

OPPTS

The EPA's Office of Pollution Prevention and Toxic Substances (**OPPTS**) developed a pollution prevention strategy for incorporating pollution prevention concepts into the EPA's ongoing environmental protection efforts.

The specific objectives of the strategy are to provide guidance and direction for efforts to incorporate pollution prevention within the EPA's existing regulatory and nonregulatory programs, and to set forth an initiative to achieve specific objectives in pollution prevention within a reasonable time frame.

The EPA's numerous activities include the following:

Coordinating development of regulations that will help identify the potential for multi-media.

Prevention strategies that reduce end of pipe compliance costs.

Examining the use of pollution prevention in enforcement actions and negotiations.

Investigating the feasibility of overcoming identified regulatory barriers to encourage cost effective (source reduction) strategies.

Working with State and local governments and trade associations to promote pollution prevention among small and medium size businesses that often lack the capital to make changes.

Investing in outside programs, usually States, by providing grant funds for the reduction of target chemicals, the agricultural and transportation industry, etc.

Providing scientific and technical knowledge necessary to implement pollution prevention. initiatives on a cross media basis, pursuant to the Pollution Prevention Research Strategic Plan.



Pollution prevention is key to protecting our beautiful surroundings from chemical wastes.

Pollution Prevention and the Pretreatment Program

Although pollution prevention is not a required element of the National Pretreatment Program, source reduction is not new to the Program.

The Pretreatment Program is designed to prevent toxic pollutants from being discharged to POTWs through controls on the sources that discharge these pollutants. Thus, pollution prevention may be considered an extension of current pretreatment program implementation activities.

For example, Pretreatment Programs have the authority to require and enforce waste management practices in order to meet NPDES permit requirements and eliminate interference with treatment facilities.

Requiring slug control plans and developing compliance schedules for improved operation and maintenance (**O&M**) procedures are examples of pollution prevention activities that have long been required by many Control Authorities. Other pretreatment program implementation tools available to make pollution prevention a more integral part of a pretreatment program include:

Inspections - Pretreatment personnel are usually quite familiar with processes performed at their local industrial facilities and have exposure to a variety of industries performing the same or similar processes; therefore, they can easily disseminate (non-confidential) information about actual pollution prevention measures implemented as well as identify new P2 opportunities.

Permits - Where local regulations allow, questions about pollution prevention measures and plans can be made part of the permit application process. Also, a permittee may be required to undergo a pollution prevention assessment and/or develop a pollution prevention plan as a condition of the permit.

Local limits - POTWs near or above maximum allowable headworks loadings may institute POTW wide-pollution prevention programs to reduce specific pollutants.

Enforcement negotiations - A pollution prevention audit may be required through a consent or compliance order, or implementation of pollution prevention measures may be required as part of a settlement.

Several Control Authorities have implemented these pollution prevention activities. For example, the City of Palo Alto, CA established a silver local limit for photoprocessors and Best Management Practices (**BMPs**) for automotive facilities. To reduce mercury loadings from dental offices, Western Lake Superior Sanitary Sewer District (**WLSSD**) in Duluth, MN developed and implemented pollution prevention BMPs.

These and many other POTWs that have successfully integrated pollution prevention into their pretreatment programs have become recognized environmental leaders in their communities.

While pollution prevention activities can be unique to each POTW, the following are key elements of successful pollution prevention programs:

Integrate pollution prevention into existing activities - POTWs that view pollution prevention as an enhancement (instead of an additional requirement) to their existing pretreatment programs make small modifications to existing pretreatment activities efficiently and effectively.

Start Small - POTWs that slowly phase in new pollution prevention activities overcome impediments such as limited resources and resistance.

Decrease pollutant loadings to POTW that result in lower O&M costs and reduce or eliminate need for capital expenditures for POTW treatment plant expansions

Enables continued or expanded growth in the community without harm to the environment.

Figure 34. Benefits of Pollution Prevention to POTWs

This approach enables pollution prevention activities to become an accepted integral part of the pretreatment program.

Define attainable goals and measure success - Short-term, narrowly focused efforts have a greater chance of succeeding. For example, POTWs have targeted a specific pollutant and group of industries, established specific pollution prevention activities, and monitored the progress and success of these activities. With each new success recorded, the benefits of pollution prevention are illustrated and the demand for further activities will grow.

Provide incentives - Incentives are effective tools for persuading users to investigate pollution prevention opportunities. POTWs have used a wide range of tools such as public recognition of pollution prevention achievements and reduction of regulatory requirements.

Benefits of Pollution Prevention

For both IUs and POTWs, pollution prevention has many benefits (Figures 34 and 35) that can be broadly categorized under tangible economic rewards and public goodwill and support. For example, pollution prevention:

Creates cost savings

Enhances process efficiency

Avoids or reduces regulatory costs

Reduces future liabilities

Improves protection of worker health

Improves public image.





Paint separation and battery collection.

P2 Implementation

Although the numerous benefits make pursuing pollution prevention attractive, implementation of source reduction in some situations may not be possible. Before implementing a pollution prevention practice, the benefits and barriers of the potential opportunity must be evaluated.



Household Hazardous Wastes or Products: paints, cleaning supplies, solvents and other products.

Figure 35. Benefits of Pollution Prevention to IUs

Common impediments include the following:

Technology

Decrease product quality.

Unable to change raw materials because of currently available technology.

Financial

Incur high costs associated with implementing alternatives (i.e., new equipment or materials, or personnel and training).

Loss due to downtime during switch overs and startups.

Foreign competitors may have an economic advantage if they are not obligated to comply with US regulations.

Binding contracts with existing waste haulers and Treatment, Storage and Disposal (TSD) facilities may exist.

Organizational

Lack of or poor communication between persons possessing the knowledge and ideas for improvements and those that can actually implement the changes.

Limited personnel or internal resources available to investigate and/or make changes.

Lack of coordination and cooperation among divisions in the corporation.

Behavioral

Alternatives may be considered inconvenient by personnel (e.g., dry sweeping then a wet wash down as opposed to just a wet wash down).

Regulatory

Elimination of regulated wastewater discharges, and hence, monitoring requirements.

Reduced paperwork requirements for waste hauling and treatment.

Compliance with RCRA reports on waste reduction (i.e., companies generating RCRA wastes are required to certify that they have a program to reduce the volume and toxicity of hazardous waste generated).

Compliance with land disposal restrictions and bans.

Environmental

Minimization of material emissions to all media resulting in reduced health risks to workers and the community.

Financial

Reduced landfill and treatment costs due to less waste being generated (includes reduced transportation costs as well).

Reduced raw material and manufacturing costs (e.g., by preventing spills or leaks, improving equipment maintenance and inventory control techniques, reuse, etc. raw materials are handled more efficiently and do not have the chance to become waste. With a greater percentage of raw material going into process, raw material use goes down in relation to volume of product produced).

Increased manufacturing efficiency and productivity and improved product quality with fewer offspec products.

Compliance and public relations

Achieving compliance with local limits and categorical standards.

Reducing waste and implementing best management practices can improve public and community relations.

Regulatory

Concentrating a pollutant for recycling may classify it as a hazardous waste (e.g., silver). As such, an industrial user may choose to discharge the pollutant rather than be subject to regulations regarding the handling, treatment and disposal of a hazardous waste.

Pollution Prevention Assistance

With the creation of the PPA came an abundance of pollution prevention related assistance. This includes direct technical assistance, training courses, and a variety of publications.

POTWs can find further information on integrating pollution prevention into their pretreatment programs in the EPA's 1993 *Guides to Pollution Prevention - Municipal Pretreatment Programs*. Specific industry trade associations and university technology transfer and outreach departments are usually aware of pollution prevention assistance materials, specific pollution prevention opportunities, and the costs and success of implementing these.

Some further sources that disseminate pollution prevention information include:

Pollution Prevention Information Clearinghouse (PPIC) - a free, nonregulatory clearinghouse available to the public which focuses on source reduction and recycling for industrial toxic wastes.

State Programs - provide technical assistance to conduct pollution prevention assessments, develop guidance manuals on conducting these assessments, actually conduct these assessments, provide assistance in developing POTW-wide pollution prevention plans, provide training for industry, State and POTW personnel, and offer grants for pollution prevention projects.

Envirosense - an on-line computer system (*internet address: es.inel.gov*) of summary information for PPIC documents, includes pollution prevention news, upcoming events, and mini-exchanges (discrete pollution prevention topic areas, pollution prevention databases, and message centers).

National Institute of Standards and Technology (NIST) - an office of the Department of Commerce, NIST develops technology to improve product quality, modernize manufacturing processes, ensure product reliability, and facilitate rapid commercialization of products based on new scientific discoveries.

NIST web sites for different industry sectors are available. For example, the metal finishing web site (i.e., the National Metal Finishing Resource Center) is found at www.nmfrc.org.



How would you dispose of used oil filters?

Other Related Subjects

Ordinance Example

Grease Removal

Combined Sewer Overflow (CSOs)

Stormwater

Concentrated Animal Feeding Operations CAFO



Toilet retrofit program are a part of pollution prevention program. Most cities are changing high water use toilets to low water use toilets 1.6 gallons to conserve water and the other big water conservation device is no-flush or waterless urinals.

Pretreatment Ordinance Example

SECTION 10.400: PRETREATMENT PROGRAM

This section adopts by reference, the applicable regulations of Title 40 Code of Federal Regulations, Part 403, "General Pretreatment Regulations for Existing and New Sources of Pollution," and other applicable State and Federal laws, including but not limited to, the Clean Water Act. These regulations are herein referred to as General Pretreatment regulations.

10.401 PURPOSE AND APPLICABILITY

(1) Purpose

This section forms the basis of the City of Sunflower pretreatment program to regulate non-domestic discharges to its sewage collection and treatment facilities. Regulation of such discharges is necessary to prevent interference with the operation of the facilities, to prevent pass-through of the treatment facilities, and to prevent any other condition which would be incompatible with the facilities.

(2) Applicability

This section shall be applicable to all non-domestic dischargers to the City's POTW.

10.402 DEFINITIONS

(1) The following words and phrases shall have the meanings herein:

Act or "the Act" means the Federal Water Pollution Control Act, also known as the Clean Water Act, 33 U.S.C. Section 1251 et seq.

Approval Authority means the Regional Administrator of the United States Environmental Protection Agency.

Approved Test Procedures means those procedures found at Title 40 Code of Federal Regulations, Part 136 and those alternate procedures approved by the Administrator of the United States Environmental Protection Agency under the provisions of Title 40.

Authorized Representative of User means a duly authorized representative of a user in accordance with the General Pretreatment Regulations.

BOD (biochemical oxygen demand) means the oxygen required for the biochemical degradation of organic material in five (5) days at twenty degrees Celsius (20°C), expressed in milligrams per liter (mg/L), as determined by approved test procedures.

Categorical User means a user that is subject to the National Categorical Standards.

City means the City of Sunflower, Texas or any authorized person acting in its behalf.

Cooling Water means the water discharged from any system of condensation, such as air conditioning, cooling, and refrigeration systems.

COD (chemical oxygen demand) means the measure of the oxygen equivalent of the organic matter content that is susceptible to oxidation by a strong chemical oxidant, expressed in mg/L as determined by approved test procedures.

Composite sample means a sample resulting from the combination of individual aliquots taken at equal intervals based on increments of time, flow or both.

Control Authority means the City Manager, Director of Public Works or a duly authorized representative.

Control Point means point of access to a user's sewer where sewage monitoring can be done.

Dilution means the addition of any material, either liquid or nonliquid, or any other method to attempt to dilute a discharge as a partial or complete substitute for adequate treatment to achieve compliance with the national categorical standards or local limits set by this section.

Director means the City of Sunflower Director of Public Works or his authorized representative unless otherwise specified.

Domestic Sewage means water-borne materials normally discharged from sanitary conveniences of dwellings, including apartment houses and hotels, office buildings, factories and institutions, free from storm water, utility and process discharges. Normal domestic sewage means normal sewage for Sunflower, Texas, in which the average daily concentration of biochemical oxygen demand (BOD) and total suspended solids (TSS) are established at two hundred-fifty (250) mg/L each, on the basis of the normal contribution of twenty-hundredths (0.20) pounds per capita per day each, and in which the average daily concentration of chemical oxygen demand (COD) is established at four hundred-fifty

(450) mg/L. It is further expressly provided that for the purpose of this section, any discharge that exceeds the above concentration of BOD, TSS or COD shall be classified as non-domestic and made subject to all regulations pertaining thereto, whether or not such discharge was partially of domestic origin.

Environmental Protection Agency (EPA) means the U.S. Environmental Agency, or where, appropriate, The Regional Water Management Division director, or other duly authorized official of said agency.

Existing Source means any source of discharge, the construction or operation of which commenced prior to the publication by EPA of proposed categorical pretreatment standards, which will be applicable to such source if the standard is thereafter promulgated in accordance with Section 307 of the Act.

General Pretreatment Regulations means Title 40 Code of Federal Regulations, Part 403, "General Pretreatment Regulations for Existing and New Sources of Pollution."

Grab sample means an individual sample collected without regard to flow in a time not to exceed fifteen minutes.

Headworks means the location where raw (untreated) sewage is introduced into the sewage treatment facilities.

Interference is as defined in the General Pretreatment Regulations.

Maximum Allowable Discharge Limit means maximum concentration of a pollutant allowed to be discharged at any time, determined from the analysis of any discrete or composite sample collected, independent of the industrial flow rate and the duration of the sampling event.

Monthly Average Limit means a discharge limit based on the average of the analytical results of all samples for a parameter taken during a calendar month using approved methods for both sampling and analysis.

National Categorical Standards means the pretreatment regulations of Title 40 of the Code of Federal Regulations, Chapter I, Subchapter N, "EPA Effluent Guidelines and Standards."

New Source shall mean the following:

(1) Any building, structure, facility or installation from which there is or may be a discharge of pollutants, the construction of which commenced after the publication of proposed Pretreatment Standards under Section 307(c) of the Act which will be applicable to such source if such standards are thereafter promulgated in accordance with that section, provided that:

(a) The building, structure, facility or installation is constructed at a site which no other source is located; or

(b) The building, structure, facility or installation totally replaces the process or production equipment that causes the discharge of pollutants at an existing source; or

(c) The production or wastewater generating processes of the building, structure, facility or installation are substantially independent of an existing source at the same site. In determining whether these are substantially independent, factors such as the extent to which the new facility is integrated with the existing plant, and the extent to which the new facility is engaged in the same general type of activity as the existing source should be considered.

(2) Construction on a site at which an existing source is located results in a modification rather than a new source if the construction does not create a new building, structure, facility or installation meeting the criteria of Title 40 CFR 403.3(k)(1)(ii) and Title 40 CFR 403.3(k)(1)(iii) but otherwise alters, replaces, or adds to existing process or production equipment.

(3) Construction of a new source as defined herein has commenced if the owner or operator has:

(1) Begun, or caused to begin as part of a continuous onsite construction program any placement, assembly, or installation of facilities or equipment; or significant site preparation work including clearing, excavation, or removal of existing buildings, structures, or facilities which is necessary for the placement, assembly, or installation of new source facilities or equipment; or

(2) Entered into a binding contractual obligation for the purchase of facilities or equipment which are intended to be used in its operation within a reasonable time. Options to purchase or contracts which can be terminated or modified without substantial loss and contracts for feasibility, engineering, and design studies do not constitute a contractual obligation.

Noncontact cooling water means water used for cooling that does not come into direct contact with any raw material, intermediate product, waste product, or finished product.

Noncategorical User means a user that is not subject to the national categorical standards.

Non-domestic Sewage means a discharge to the POTW that is not domestic sewage.

Nonprocess flows means sewage that is not classified as domestic or process, such as noncontact cooling water, cooling tower blowdown, air conditioner condensates, and demineralizer blowdown.

Outfall means a discharge of sewage that is expressly identified by the Control Authority for control and monitoring purposes.

Overload means the imposition of mass or hydraulic loading on a treatment facility in excess of its engineered design capacity.

Pass-through means a discharge which exits the POTW into waters of the United States in quantities or concentrations which, alone or in conjunction with a discharge or discharges from other sources, is a cause of a violation of any requirement of the City of Sunflower NPDES permits, including an increase in the magnitude or duration of a violation.

Person means any individual, partnership, co-partnership, firm, company, corporation, association, joint stock company, trust, estate, governmental entity, or any other legal entity; or their legal representatives, agents, or assigns. This definition includes all Federal, State and local governmental entities.

pH means the logarithm (base 10) of the reciprocal of the hydrogen ion concentration.

Pollutant means dredged spoil, solid waste, incinerator residue, filter backwash sewage, garbage, sewage sludge, munitions, medical wastes, chemical wastes biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt, municipal, agricultural and industrial wastes, and certain characteristics of wastewater (e.g., pH, temperature, TSS, turbidity, color, BOD, COD, toxicity, or odor).

POTW (Publicly Owned Treatment Works) means the sewage treatment works owned by the City of Sunflower. This definition includes any devices and systems used in the storage, treatment, recycling and reclamation of sewage. It includes sewers, pipes, and other conveyances only if they convey sewage the City of Sunflower POTW.

Pretreatment means the reduction of the amount of pollutants, the elimination of pollutants, or the alteration of the nature of pollutant properties in wastewater prior to or in lieu of discharging or otherwise introducing such pollutants into a POTW. The reduction or alteration may be obtained by physical, chemical or biological processes, process changes or by other means, except as prohibited by 40 CFR 403.6(d).

Pretreatment Requirements means all of the requirements that are set forth in this ordinance.

Process Flow means sewage that is generated during manufacturing or processing, which comes into direct contact with or results from the production or use of any raw material, intermediate product, finished product, by-product, or waste product.

Removal is as defined in the General Pretreatment Regulations.

Sewage means solids, liquids, or gaseous materials discharged to the City's POTW. Sewage includes both domestic and non-domestic sewage.

Sewer (sanitary sewer) means an artificial pipe or channel that carries sewage and to which storm water and ground water are not intentionally admitted.

Significant User means a user that is: (1) subject to national categorical standards; (2) discharges an average of twenty-five thousand (25,000) gallons per day (gpd) or more of process flow to the POTW; (3) discharges of process flow which makes up five (5) percent or more of the average dry weather hydraulic or organic capacity of the POTW treatment plant, or; (4) has a reasonable potential, in the opinion of the Control Authority, to adversely affect the POTW treatment plant.

Slug Load means any discharge at a flow rate or concentration which could cause a violation of the prohibited discharge standards stated herein.

Standard Industrial Classification (SIC) means a classification pursuant to the Standard Industrial Classification Manual issued by the Office of Management and Budget.

Storm Water means any flow occurring during or following any form of natural precipitation, and resulting from such precipitation, including snowmelt.

Surcharge means the additional wastewater service charge incurred by any user discharging waste containing higher concentrations of BOD, TSS and COD than those defined for domestic sewage herein.

To Discharge includes to deposit, conduct, drain, emit, throw, run, allow to seep, or otherwise release or dispose of, or to allow, permit or suffer any of these acts.

TSS (total suspended solids, nonfilterable residue) means solids that either float on the surface or are in suspension, measure at one hundred-three to one hundred-five degrees Celsius (103-105°C), expressed in mg/L, as determined by approved test procedures.

User means a discharger of any non-domestic sewage to the POTW. A user includes, but is not limited to, any individual, firm, company, partnership, corporation, group, association, organization, agency, city, county, or district.

The meaning of all terms used in this ordinance that are not defined above shall be as defined in Title 40, Code of Federal Regulations.

10.403 PRETREATMENT STANDARDS

There are three types of pretreatment standards: prohibited discharge standards - including general, specific, and dilution prohibitions; national categorical standards; and local limits. These standards shall apply to a user whether or not the user is subject to other federal, state, or local requirements.

The standards in this subsection shall apply to each user, as applicable. Users in an industrial manufacturing category specified in Title 40 of the Code of Federal Regulations Chapter I, Subchapter N, "EPA Effluent Guidelines and Standards,": shall be subject to prohibited discharge standards, national categorical standards, and local limits. Other users shall be subject to prohibited discharge standards and local limits. Where these standards overlap, the most stringent standard shall apply to the user.

The Control Authority, at his discretion, has the right to apply these standards to individual non-domestic discharges before they are commingled.

(1) Prohibited Discharge Standards

(a) General Prohibitions

A user may not discharge to the POTW any material which causes pass-through or interference.

(b) Specific Prohibitions

The following shall not be discharged to the POTW:

(i) Discharges which are capable of creating a fire or explosion hazard in the POTW. These discharges include, but are not limited to, discharges with a closed cup flashpoint of less than one hundred forty degrees Fahrenheit (140°F), as determined by a Pensky-Martens Closed Cup Tester, using the test method specified in ASTM (American Society for Testing and Materials) standard D-93-79 or D-93-80K or a Seta flash Closed Cup Tester, using the test method specified in ASTM standard D-3278-78;

(ii) Discharges which will cause corrosive structural damage to the POTW, but in no case discharges with pH lower than 5.5 or greater than 9.5;

(iii) Discharges containing solid or viscous materials in amounts which will cause obstruction to the flow in or proper operation of the POTW resulting in interference. Discharges shall not contain any materials such as wax, grease, oil, or plastics that will solidify or become discernibly viscous at temperatures between thirty-two and one hundred-fifty degrees Fahrenheit (32-150°F). Discharges shall not contain petroleum oil, nonbiodegradable cutting oil, or products of mineral oil origin in amounts that will cause interference or pass through. Discharges shall not contain any materials such as ashes, cinders, sand, mud, straw, shavings, metal, glass, rags, feathers, tar, plastics, wood, whole blood, paunch manure, hair and fleshings, entrails, lime slurry, lime residues, slops, chemical residues, paint residues or bulk solids in such quantities capable of causing interference with the POTW. Discharges shall not contain free or emulsified oil and grease in combination exceeding one hundred (100) mg/L;

(iv) Discharges having a temperature higher than one hundred-fifty degrees Fahrenheit (150°F) (sixty-five degrees Celsius, 65°C), or any discharge which contains heat in amounts which will inhibit biological activity or cause interference with the POTW, but in no case heat in such quantities that the temperature at the headworks of the POTW exceeds one hundred-four degrees Fahrenheit (104°F) (forty degrees Celsius, 40°C);

(v) Discharges that contain any noxious or malodorous materials which can form a gas, which either singly or by interaction with other discharges, are capable of causing objectionable odors; or hazard to life; or creates any other condition deleterious to the POTW; or requires unusual provisions, attention, or expense to handle;

(vi) Discharges which result in the presence of toxic gases, vapors, or fumes within the POTW in a quantity that may cause acute workers health and safety problems;

(vii) Discharges that are capable of causing excessive discoloration in the POTW effluent;

(viii) Discharges with unusual flow and concentration, including those with oxygen demanding materials, at a flow rate or concentration which will cause interference with the POTW, or if such materials can cause damage to collection facilities, impair the treatment processes, incur excessive treatment cost, or cause the City to be noncompliant with the conditions of its discharge permits;

(ix) Discharges containing a BOD (biochemical oxygen demand) or TSS (total suspended solids) concentration in excess of 7,000 mg/L;

(x) Discharges classified by the Texas Natural Resource Conservation Commission as hazardous waste at 31 TAC (Texas Administrative Code) Chapter 335 without the written approval of the Control Authority;

(xi) Discharges containing radioactive materials without the written approval of the Control Authority;

(xii) Materials that are trucked or hauled in, except at discharge points that are designated by the Control Authority; or

(xiii) Discharges from steam cleaning and chemical cleaning businesses unless a facility or process is provided that will produce an effluent compliant applicable Pretreatment Requirements. There shall be no discharge of visible foam.

(c) Dilution Prohibitions

(i) No user shall ever add any material, either liquid or nonliquid, or in any other way attempt to dilute a discharge as a partial or complete substitute for adequate treatment to achieve compliance with the national categorical standards or local limits.

(ii) This prohibition does not include dilution which is a normal part of the production process or a necessary part of the process to treat a waste, such as adding lime for neutralization or precipitation, or the mixture of compatible wastes in order to treat at capacity levels rather than treating wastes in small batches.

(iii) The Control Authority, at his discretion, may impose mass limitations on a user that is using dilution to meet applicable pretreatment standards or requirements, or in cases where the imposition of mass limitations is appropriate.

(2) National Categorical Standards

National Categorical standards apply to specific industrial subcategories under Title 40 of the Code of Federal Regulations, Chapter I, Subchapter N, "EPA Effluent Guidelines and Standards." A user that falls into one of these subcategories shall be subject to the pretreatment standards applicable to that subcategory and is classified as a categorical user.

(3) Local Limits

Local limits are quantitative limits on discharges applicable to all users. Local limits are designed to meet the general and specific prohibitions in 10.403(1)(a) and (b) of this ordinance.

(a) Existing Local Limits

Local limits are periodically reviewed by the Control Authority and revised as necessary to respond to changes in federal, state, or local regulations, environmental protection criteria, plant design and operational criteria, and the nature of industrial discharges to the POTW. Local limits are as follows:

Constituent*	Maximum Allowable Concentration in a Daily Composite, mg/L
Cadmium	0.2
Chloroform	4
Chromium (total)	17
Copper	3.5
Ethyl benzene	16
Lead	0.5
Naphthalene	15
Nickel	4.5
Silver	0.07
Tetrachloroethylene(perchloroethylene)	5
Toluene	14
Zinc	3.8

***limits for metals based on unfiltered samples**

(b) Case-by case Local Limits

Local limits that have not yet been established for a material may be developed on a case-by-case, user specific basis. A user must have the case-by-case local limit(s) included in a permit before discharging to the POTW.

10.404 SIGNIFICANT USERS

(1) Option to Exclude Noncategorical Users

The Control Authority need not list as significant any noncategorical user that, in the opinion of the Control Authority, has no potential for adversely affecting the POTW's operation or for violating any of the Pretreatment Requirements.

(2) Delisting of Noncategorical Users

Any noncategorical user that has been listed as a significant user may petition the Control Authority to be removed from the significant user list and reclassified as nonsignificant on the grounds that it has no potential for adversely affecting the POTW's operation or for violating any of the Pretreatment Requirements.

(3) Notification Requirements

If a noncategorical user has been listed as a significant user by the control Authority for whatever reason, prior to removal from the list, the control Authority will notify the Approval Authority.

10.405 Discharge Permits

(1) Applicability

All users shall obtain a permit from the Control Authority in order to discharge non-domestic sewage to the City's POTW. Permit applications shall be submitted to the Control Authority prior to permit issuance. Either the owner or operator of a user's facility shall submit the application.

(2) Denial or Condition of Permit

The Control Authority has the right to deny or condition a permit for any non-domestic discharges that do not meet the Pretreatment Requirements or would cause the City to be noncompliant with the conditions of the City's discharge permits.

(3) Permit Conditions

(a) Minimum Conditions

The permit will contain the following minimum conditions:

- (i) Period during which the permit is effective, in no case greater than five years;
- (ii) Transferability of the permit to a new owner or operator allowable only with notification and approval of Control Authority;
- (iii) Limits on the volume and quality of sewage discharged based on the Pretreatment Standards;
- (iv) Requirements for self-monitoring programs such as location, type, and frequency of sampling, measurement, and analysis; and
- (v) Requirements for notifications, reports, and recordkeeping.
- (vi) A statement of applicable civil and criminal penalties for violation of pretreatment standards and requirements, and any applicable compliance schedule. Such schedules may not extend the compliance date beyond applicable federal deadlines.

(b) Other Conditions

The following conditions, as applicable, will be in the permit:

- (i) Conditions and compliance schedule necessary to achieve compliance with the Pretreatment Requirements.
- (ii) Plans to prevent and control spills and batch discharges;
- (iii) Any other conditions necessary to ensure compliance with the Pretreatment Requirements, and other federal, state and local requirements, and;
- (vi) A statement requiring that all reports contain the certification statement at 40 CFR 403.6(a)(2).

(4) Permit Application Form

Applications for new permits, permit renewals, and permit modifications shall be made on a standard form provided by the Control Authority. Applications shall be submitted to the Control Authority.

(5) Existing Users

Significant users with existing non-domestic discharges prior to March 14, 1990, shall submit a permit application before September 15, 1990. Other users with existing non-domestic discharges prior to March 14, 1990 shall submit a permit application before June 15, 1990. Existing users shall be allowed to discharge non-domestic sewage without a permit until the Control Authority has issued the user a permit, if the user has submitted a permit application with the applicable time period.

(6) New Users

A new user shall submit a permit application and obtain a permit before discharging to the POTW. An application shall be submitted by significant users at least one hundred eighty (180) days before the date the discharge will begin. It is recommended that an application be submitted by other user at least ninety (90) days before the date the discharge will begin.

(7) Discharge and Permit Modifications

If a user with a discharge permit wishes to add or change a process or operation which would change the nature or increase the quantities of materials discharged to the POTW such that the user would be noncompliant with the user's permit requirements or the Pretreatment Requirements, the user shall obtain approval by the Control Authority prior to making these additions or changes to the discharge. Approval shall be given by the Control Authority by a modification, or revocation and re-issuance of the permit. A significant user shall submit an application for permit modification at least one hundred eighty (180) days before the date the change in discharge is expected to begin. It is recommended that an application be submitted by other users at least ninety (90) days before the date the change in discharge is expected to begin.

(8) Permit Renewal

A permit may have a period of duration up to five (5) years. A permit shall be renewed by submitting an application for renewal. An application shall be submitted by significant users at least one hundred eighty (180) days before the expiration date of the existing permit. An application for other users shall be submitted at least ninety (90) days before the expiration date of the existing permit.

(9) Re-opening of Permit

The Control Authority has the right to re-open a permit before its expiration date to include compliance schedules, or to achieve compliance with new or revised Pretreatment Requirements, federal, state, or local requirements.

(10) Changes in Owner or Operator

(a) Transfer of Permit

A permit shall only be transferred to a new owner or operator if the following conditions are met. The expiration date of the permit is not extended by the transfer. The control Authority will send to the owner or operator a revision to the permit to reflect the change in owner or operator.

(i) The nature of the discharge or operation of the facility will not change under the new owner or operator;

(ii) The current owner or operator notifies the Control Authority at least thirty (30) days in advance of the proposed transfer date;

(iii) The notification includes a written agreement between the current and new owner or operator continuing a specific date for transfer of permit responsibility, coverage, and liability between them; and

(iv) The Control Authority does not notify the current and new owner or operator of the Control Authority's intent to revoke and reissue the permit. If the Control Authority does not notify, the transfer is effective on the date specified in the written agreement.

(b) Revocation and Re-issuance of Permit

If above conditions in paragraph (a) are not met, the Control Authority shall require the new owner or operator to submit a permit application as a new user and obtain a permit before discharging to the POTW. In addition, the current owner or operator shall notify the Control Authority at least thirty (30) days in advance of the proposed date on which the ownership will change.

10.406 REMOVAL CREDITS

(1) The Control Authority may, at his discretion, grant removal credits to a categorical user to reflect removal by the POTW of materials specified in the national categorical standards. The Control Authority may grant a removal credit equal to or, at his discretion, less than the POTW's consistent removal rate. Removal credits may only be given for indicator or surrogate materials regulated in a national categorical standard if the standard so specifies.

(2) A user shall submit a removal credit application to the Control Authority. Written approval by the Control Authority shall be obtained prior to taking the removal credit. Application shall be made on a standard form provided by the Control Authority.

(3) The Control Authority has the right to grant removal credits only after meeting the requirements of the General Pretreatment Regulations.

10.407 NOTIFICATION REQUIREMENTS

Notification to the Control Authority is required for any of the following. The timing, content, and form of notification are established either in the discharge application or discharge permit, as applicable.

- (1) A condition or event that would cause pass-through of or interference with the POTW, including slug loadings as defined by 10.402 and 10.403 herein.
- (2) Permit noncompliance.
- (3) Bypasses and upsets.
- (4) A change in pretreatment processes.
- (5) A change in monitoring facilities such as location and type of equipment.
- (6) Discharges of hazardous waste.
- (7) Discharges containing radioactive materials.
- (8) Other appropriate conditions or events to ensure compliance with the Pretreatment Requirements, and other federal, state, or local requirements.

10.408 REPORTING REQUIREMENTS

(1) Baseline Report

Categorical users shall submit baseline reports in accordance with the General Pretreatment Regulations.

(a) Within either one hundred eighty (180) days after the effective date of the categorical pretreatment standard, or the final administrative decision on a category determination under 40 CFR 403.6(a)(4), whichever is later, existing categorical users currently discharging to or scheduled to discharge to the POTW shall submit to the Control Authority a report which contains the information listed in paragraph (b) below. At least ninety days prior to commencement of their discharge, new sources, and sources that become categorical users subsequent to the promulgation of an applicable categorical standard, shall submit to the Control Authority a report which contains the information listed in paragraph (b) below. A new source shall report the method of pretreatment it intends to use to meet applicable categorical standards. A new source also shall give estimates of its anticipated flow and quantity of pollutants to be discharged.

(b) Users described above shall submit the following:

(i) Identifying Information - The name and address of the facility, including the name of the operator and owner.

(ii) Environmental Permits - A list of any environmental control permits held by or for the facility.

(iii) Descriptions of Operations - A brief description of the nature, average rate of production, and standard industrial classifications of the operation(s) carried out by such user. This description should include a schematic process diagram which indicates points of discharge to the POTW from the regulated processes.

(iv) Flow Measurement - Information showing the measured average daily and maximum daily flow, in gallons per day, to the POTW from regulated process streams and other streams, as necessary, to allow use to the combined wastestream formula.

(v) Measurement of Pollutants - The categorical pretreatment standards applicable to each regulated process. The results of sampling and analysis identifying the nature and concentration, and/or mass, where required by the standard or by the Control Authority, of regulated pollutants in the discharge from each regulated process. Instantaneous, daily maximum, and long-term average concentrations, or mass, where required, shall be reported. The sample shall be representative of daily operations and shall be collected and analyzed in accordance with procedures set out in 40 CFR 136.

(vi) Signature and Certification - All baseline monitoring reports must be signed and certified in accordance with 40 CFR 403.6 (a)(2).

(2) Compliance Schedule Progress Reports

(a) Should additional pretreatment or operation and maintenance be required to meet pretreatment standards, a compliance schedule will be issued. The schedule shall contain progress increments in the form of dates for the commencement and completion of major events leading to the construction and operation of additional pretreatment facilities required for the user to meet the applicable pretreatment requirements.

(b) No increment shall exceed nine months;

(c) The user shall submit a progress report to the Control Authority no later than fourteen days following each date in the schedule and the final date of compliance. This report shall include as a minimum, whether or not the user complied with the progress increments, reasons for any delays, and steps being taken by the user to return to the established schedule;

(3) Reports on Compliance with Categorical Pretreatment Standard Deadline

Within ninety days following the date for final compliance with applicable categorical pretreatment standards, or in the case of a new source following commencement of the introduction of wastewater into the POTW, any user subject to such pretreatment standards and requirements shall submit to the Control Authority a report containing the information described in 10.408(1)(b) herein. For users subject to equivalent mass or concentration limits established in accordance with 40 CFR 403.6(c), this report shall contain a reasonable measure of the user's long-term production rate. For all other users subject to categorical pretreatment standards expressed in terms of allowable pollutant discharge per unit of production this report shall include the user's actual production during the appropriate sampling period. All compliance reports must be signed and certified in accordance with 40 CFR 403.6(a)(2). Categorical users shall submit reports in accordance with the General Pretreatment Regulations on compliance schedule progress, compliance with categorical pretreatment standard deadlines, and continued compliance with categorical pretreatment standards.

(4) Periodic Reports on Continued Compliance

(a) All significant industrial users shall, at a frequency determined by the Control Authority but in no case less than twice per year, submit a report indicating the nature and concentration of pollutants and the estimated or measured daily maximum and average flows of the discharges to which pretreatment requirements are applicable. All periodic reports must be signed and certified in accordance with 40 CFR 403.6(a)(2).

(b) The Control Authority may require all other users and/or persons discharging non-domestic wastewater into the POTW to submit appropriate reports concerning the nature and concentration of pollutants in the discharge.

(5) Reports of Additional Samples Taken

If a user subject to pretreatment requirements monitors any pollutant more frequently than required using approved test procedures, the results of this monitoring shall be included in the periodic reports.

(6) Repeat Sampling and Reporting

If sampling performed by a user indicates a violation, the user must notify the Control Authority with twenty-four (24) hours of becoming aware of the violation. The user shall also repeat the sampling and analysis and submit the results of the repeat analysis to the Control Authority within thirty (30) days after becoming aware of the violation.

(7) Sample Collection and Monitoring Requirements

All sampling techniques and pollutant analyses used for compilation of data required to be submitted as part of a wastewater discharge application or report required by any pretreatment requirement shall be performed in accordance with the techniques prescribed in Title 40, Code of Federal Regulations, Part 136 unless otherwise specified in an applicable categorical pretreatment standard.

(8) Additional Reports

The Control Authority has the right to request any additional reports from a user that are necessary to assess and assure compliance with the Pretreatment Requirements.

(9) Record Keeping

(a) Users subject to the reporting requirements of this ordinance shall retain, and make available for inspection and copying, all records of information obtained pursuant to any monitoring activities required by this ordinance and additional records obtained pursuant to monitoring activities undertaken by the user independent of such requirements.

(b) Records shall include the date, exact place, method, and time of the sampling and the name of the person(s) taking the sample; dates analyses were performed; who performed the analyses; the analytical techniques or methods used; and the results of the analyses.

(c) Records shall remain available for a period of at least three (3) years. This period shall be automatically extended for the duration of any litigation concerning the user of the Control Authority, or where the user has been specifically notified of a longer retention period by the Control Authority.

10.409 PRETREATMENT FACILITIES

Users shall provide pretreatment facilities if they are necessary in order to comply with the pretreatment standards in 10.403 of this ordinance.

(1) Approval of Proposed Pretreatment Facilities

Plans, specifications, and any other pertinent information related to proposed pretreatment facilities for significant users shall be submitted to the Control Authority. Other users may be requested by the Control Authority to submit plans, specifications, and any other pertinent information related to proposed pretreatment facilities. Construction of such facilities prior to acceptance by the Control Authority may be done solely at the risk of the user. This acceptance shall in no way relieve the user of the obligation to install, operate, maintain and, if necessary, modify the pretreatment facilities to maintain compliance with the Pretreatment Requirements. Pretreatment facilities shall be constructed so as to provide the following:

- (a) Prevention of prohibited discharges from entering a sewer;
- (b) Control of the quantities and rates of discharge of non-domestic sewage into a sewer; and
- (c) An accessible entry so that any authorized employee of the City may readily and safely inspect and monitor the non-domestic discharges.

(2) Pretreatment Facilities To Be Maintained

Pretreatment facilities shall be maintained in satisfactory and effective operation by the user at the user's expense. Operation and maintenance records shall be maintained by the user as specified in the user's discharge permit.

(3) Accidental Discharge/Slug Control Plans

Users discharging non-domestic wastewater into the POTW shall provide protection from the accidental discharge of prohibited wastes. Prior to the commencement of any non-domestic discharge and at least once every two years the Control Authority shall evaluate whether each significant user requires an accidental discharge/slug control plan. The Director may require any user to develop, submit for approval, and implement such a plan. Alternatively, the Director may develop such a plan for any user. Each plan shall include the following as a minimum:

- (a) Description of discharge practices, including non-routine batch discharges;
- (b) Description of stored chemicals;
- (c) Procedures for immediately notifying the Director of any accidental or slug discharge, as required by section 10.407 of this ordinance.
- (d) Procedures to prevent adverse impact from any accidental or slug discharge. Such procedures include, but are not limited to, inspection and maintenance of storage areas, handling and transfer of materials, loading and unloading operations, control of plant site runoff, worker training, building of containment structures or equipment, measures for containing toxic organic pollutants, measures and equipment for emergency response and any other procedures deemed necessary to prevent accidental/slug discharges from entering the POTW.

(4) Additional Pretreatment Measures

- (a) Whenever deemed necessary, the Control Authority may require user to restrict their discharge during peak flow periods, designate that certain wastewater be discharged only into specific sewers, relocate and/or consolidate points of discharge, separate sewage wastestreams from industrial wastestreams, and such other conditions as may be necessary to protect the POTW and determine the user's compliance with the requirements of the ordinance.
- (b) Grease, oil and sand interceptors shall be provided when deemed necessary by the Control Authority for the proper handling of wastewater containing excessive amounts of grease and oil or sand. Such interceptors shall not be required for residential users. All interception units shall be of type and capacity approved by the Control Authority and shall be so located to be easily accessible for cleaning and inspection. Such interceptors shall be inspected, cleaned, and repaired regularly, as needed, by the user at their expense.

(c) Users with the potential to discharge flammable substances may be required to install and maintain an approved combustible gas detection meter.

10.410 INSPECTION, SURVEILLANCE, AND MONITORING

(1) Minimum Monitoring Requirements

(a) Significant users shall be required to self-monitor to meet, at a minimum, the requirements of the General Pretreatment Regulations.

(b) Users that have the potential to routinely discharge non-domestic sewage that contains concentrations of BOD, TSS, and COD higher than those defined for domestic sewage herein shall be independently monitored by the City for flow, BOD, TSS, COD and pH at least once a year. The Control Authority shall determine which users have this potential.

(c) The City shall independently monitor all other users for flow, BOD, TSS, COD, and pH at a frequency in relation to their potential impact on the POTW, as determined by the Control Authority.

(d) The Control Authority may increase the frequency and/or add parameters to a user's self-monitoring program or the City's independent monitoring program to ensure compliance with the Pretreatment Requirements.

(2) Sampling and Analysis

(a) Significant users shall meet the requirements of the General Pretreatment Regulations for sampling and analysis. Other users shall meet the requirements for sampling and analysis as stated herein or in the user's control document.

(b) For all users, containers, preservation techniques, and holding times for samples shall comply with methods and procedures found at Title 40 Code of Federal Regulations, Part 136.

(c) For all users, sample analysis shall be in accordance with approved test procedures. The Control Authority, at this discretion, may specify which approved test procedure shall be used.

(d) Type of samples (grab or composite) and flow measurement shall be consistent with the type of discharge and parameters being regulated and shall be specified by the Control Authority in the permit.

(3) Control Point

A user shall provide a control point for the purpose of sampling and flow measurement. The location and design of the control point shall be approved by the Control Authority. The control point shall be placed so that non-domestic sewage can be sampled and measured prior to any commingling with domestic sewage or non-process flows.

Written approval of exceptions to this requirement shall be obtained by a user from the Control Authority. It is recommended that the control point for sampling and flow measurement be at the same location. Flow may be determined by water supply meter measurements if no other flow device is available and no other source of raw water is used. Other methods for estimating wastewater discharge flow must be approved by the Control Authority.

(4) Inspection and Entry

The Control Authority or his duly authorized representative, Federal and State Officials, upon presentation of credentials and other documentation as may be required by law, shall be permitted to gain access to such properties as may be necessary for the purpose of inspection, observation, sampling, set up and use of monitoring equipment, and inspection and copying of records having a direct bearing on the discharges of non-domestic sewage. Unreasonable delays in allowing access to the user's premises shall be a violation of this ordinance.

(5) Use of Contractors

The Control Authority may select an independent contractor to conduct the independent monitoring by the City.

10.411 ENFORCEMENT

(1) Administrative Order

In addition to any other actions or remedies authorized in this ordinance, the Control Authority or its duly authorized representative is authorized to enforce this ordinance through the exercise of any one or more of the following administrative actions. Unless otherwise expressly set forth herein, the selection or use of one such action or remedy by the Control Authority shall not be construed to prevent the Control Authority from pursuing any other enforcement actions or remedies nor require the pursuit of a particular action or remedy as a condition precedent to the use of any other such action or remedy.

(2) Notice of Violation

The Control Authority shall serve a user that is found non-complaint with the Pretreatment Requirements with a notice stating the nature of the noncompliance. This notice may or may not be in writing.

Any violation of pretreatment standards incurs immediate liability. Each day of violation constitutes a separate noncompliance.

Within thirty (30) days after the date of receipt of this notice, a user shall submit a written response to the Control Authority with an explanation of the noncompliance, what steps are currently being taken to prevent the noncompliance, and a plan for the correction and continued prevention of the noncompliance. Submission of this response in no way relieves the user of liability for any violations occurring before or after receipt of the notice of violation.

(3) Consent Order

The Control Authority may enter into Consent Orders, assurances of voluntary compliance, or other similar documents establishing an agreement with any user responsible for noncompliance. Such documents will include specific action to be taken by the user to correct the noncompliance within a time period specified by the document.

(4) Show Cause Hearing

The Control Authority may order a user which has violated or continues to violate, any provision of this ordinance, a wastewater discharge permit or enforcement action issued, or any other pretreatment requirement, to appear the Director and show cause why the proposed enforcement action should not be taken. Notice shall be served on the user specifying the time and place for the meeting, the proposed enforcement action, the reasons for such action, and a request that the user show cause why the proposed enforcement action should not be taken. The notice of the meeting shall be served by hand or certified mail at least ten days prior to the hearing. Such notice may be served on any authorized representative of the user. A show cause hearing shall not be a bar against, or prerequisite for, taking any other action against the user.

(5) Compliance Order/Compliance Schedules

(a) Applicability

If a user cannot comply with the pretreatment standards in section 10.403 or any other pretreatment requirement, the Control Authority may provide a compliance order containing a schedule for achieving compliance.

(b) Allowable Time for Compliance

The compliance schedule shall be the shortest time in which the user is able to provide pretreatment facilities or changes in operation and maintenance that will achieve compliance. If a user is given a compliance schedule for national categorical standards, the completion date of this schedule shall not be later than the compliance date established for the applicable national categorical standard and shall be in accordance with the General Pretreatment Requirements. A user shall not continue

discharging in noncompliance of the Pretreatment Requirements beyond the time limit provided in the compliance schedule.

(c) Form of Compliance Schedule

Compliance schedules may be provided by the Control Authority by notice of noncompliance, enforcement order, or as part of the discharge permit. The Control Authority has the right to re-open a user's discharge permit in order to add a compliance schedule.

(6) Cease and Desist Order

When the Control Authority finds that a user has violated, or continues to violate, any provision of this ordinance, a wastewater discharge permit or order issued herein, or any other pretreatment standard or requirement, or that the user's past violations are likely to recur, the Control Authority may issue an order to the user directing it to cease and desist all such violations and directing the user to:

- (a) Immediately comply with all requirements; and
- (b) Take such appropriate remedial or preventive actions may be needed to properly address a continuing or threatened violation, including halting operations and/or terminating the discharge.

(7) Authority to Disconnect Service

(a) Conditions for Disconnection

The City shall have the right to disconnect a user's sewer service when a user's discharge reasonable appears to:

- (i) Damage sewer lines or POTW treatment processes;
- (ii) Cause the City to be noncompliant with the conditions of its discharge permits;
- (iii) Present an endangerment to the environment or which threatens to interfere with the operation of the POTW; or
- (iv) Present an imminent endangerment to the health or welfare of persons.

(b) Notification

In the case of an imminent endangerment to the health or welfare of persons, the Control Authority shall give oral or written notice to a user before disconnecting sewer service. Under all other conditions for disconnection, the control Authority shall give written notice to a user before disconnection. Within ten (10) days after receipt of notification of disconnection, the user must submit a written response to the Control Authority with an explanation of the cause of the problem and what measures have and will be taken to prevent any future occurrence. Submission of this response in no way relieves the user of liability for any violations occurring before or after receipt of the notice of disconnection.

(c) Reconnection of Service

The user's sewer shall remain disconnected until such time that the user has demonstrated that the cause of this noncompliance has been eliminated.

(d) Liability

The City shall not be liable for any resulting damage to the user's property as a result of disconnection under the conditions for disconnection.

(8) Termination of Permit

A user that violates any of the following conditions may be subject to permit termination:

- (a) Failure to report a reasonable estimate of the volume and quality of its non-domestic sewage.
- (b) Failure to notify the Control Authority of a change in process or operation which would significantly change the nature or increase the quantities of materials discharged to the POTW that would cause the user to be noncompliant with its discharge permit requirements or the Pretreatment Requirements.

- (c) Refusal of right of entry to the user's premises in accordance with Subsection I of this ordinance.
- (d) Intentional violation of permit conditions.
- (e) Falsifying information.
- (f) Failure to pay sewer charges or fines.

(9) Injunctive Relief

The Control Authority may seek injunctive relief to restrain or compel actions of a user.

(10) Civil and Criminal Penalties

The Control Authority has the right to seek or assess civil or criminal penalties in at least the amount of one thousand dollars (\$1000) per day for each violation of the user's permit or the Pretreatment Requirements.

10.411.01 Affirmative Defenses to Discharge Violations

(1) Upset

(a) Upset means an exceptional incident in which there is unintentional and temporary noncompliance with pretreatment requirements because of factors beyond the reasonable control of the user. An upset does to include noncompliance to the extent caused by operational error, improperly designed treatment facilities, inadequate treatment facilities, lack of preventive maintenance, or careless or improper operation.

(b) An upset shall constitute an affirmative defense to an action brought for noncompliance with pretreatment requirements if the following provisions are met.

(c) A user who wishes to establish the affirmative defense of upset shall demonstrate through properly signed contemporaneous operating logs or other relevant evidence that:

- (i) An upset occurred and the user can identify the cause(s) of the upset;
- (ii) The facility was being operated properly and in compliance with applicable and appropriate operation and maintenance procedures; and
- (iii) The user has submitted the following information to the Control Authority within twenty-four (24) hours of becoming aware of the upset:

A description of the nature of the discharge and cause of the noncompliance;

The period of noncompliance, including the exact dates and times or, if not corrected, the anticipated time the noncompliance is expected to continue;

Steps being taken and/or planned to reduce eliminate, and prevent recurrence of the noncompliance.

(vi) In any enforcement proceeding, the user seeking to establish the occurrence of an upset shall have the burden of proof.

(v) Users will have the opportunity for judicial determination on any claim of upset only in an enforcement action brought for noncompliance with categorical pretreatment standards.

(vi) Users shall control production of all discharges to the extent necessary to maintain compliance with pretreatment requirements upon reduction, loss, or failure of its treatment facility until the facility is restored or an alternative method of treatment is provided.

This requirement applies in the situation where, among other things, the primary source of power for the treatment facility is reduced, lost, or fails.

(2) Bypass

(a) Bypass means the intentional diversion of wastestreams from any portion of a user's treatment facility.

(b) Severe property damage means substantial physical damage to property, damage to the treatment facilities which causes them to become inoperable, or substantial and permanent loss of natural resources which can reasonably be expected to occur in the absence of a bypass.

(c) A user may allow any bypass to occur which does not cause pretreatment standards or requirements to be violated, but only if it also is for essential maintenance to assure efficient operation.

(d) If a user knows in advance of the need for a bypass, it shall submit prior notice to the Control Authority at least ten days before the date of the bypass, if possible.

A user shall submit oral notice to the Control Authority of an unanticipated bypass that exceeds applicable pretreatment requirements within twenty-four hours from the time it becomes aware of the bypass. A written submission shall also be provided within five days from the time the user becomes aware of the bypass. The written submission shall contain a description of the bypass and its cause; the duration of the bypass, including exact dates and times, and, if the bypass has not been corrected, the anticipated time it is expected to continue; and steps taken or planned to reduce eliminate, and prevent reoccurrence of the bypass. The Control Authority may waive the written report on a case-by-case basis if proper oral notice has been given.

(e) Bypass is prohibited, and the Control Authority may take an enforcement action against a user for a bypass, unless

(i) Bypass was unavoidable to prevent loss of life, personal injury, or severe property damage;
(ii) There were no feasible alternatives to the bypass, such as the use auxiliary treatment facilities, retention of untreated wastes, or maintenance during normal periods of equipment downtime. This condition is not satisfied if adequate back-up equipment should have been installed in the exercise of reasonable engineering judgment to prevent a bypass which occurred during normal periods of equipment downtime or preventive maintenance; and
(iii) The user submitted notices as stated herein.

(iv) The Control Authority may approve an anticipated bypass, after considering its adverse effects, if the Control Authority determines that it will meet the three conditions in paragraph (e) above.

10.412 FEE SCHEDULE *Example*

(1) Applications

A user is subject to the following application fees:

	Significant Users	Other Users
New Permit	\$100	\$25
Permit Renewal	\$100	\$25
Permit Modification	\$100	\$25

Removal credit - A fixed fee for a removal credit application cannot be given because of the circumstances of each user and constituent the credit is applied for are highly variable. Any user or group of users wishing to apply for a removal credit shall assume responsibility for all costs incurred by the City.

(2) Surcharge for Higher Concentrations

Users shall be assessed a sewer surcharge for non-domestic sewage that contains concentrations of BOD, TSS, and COD higher than those defined for domestic sewage herein. The surcharge shall be in addition to any other sewer charges required by other City ordinances. If a user has more than one non-domestic outfall identified in a permit, the surcharge shall be applicable to the daily average total of all non-domestic discharges and not the individual non-domestic discharges.

(a) When Surcharge Shall Be Applied

A user shall be subject to a surcharge when its non-domestic discharge daily average total:

- (i) Exceeds a BOD concentration of two hundred-fifty (250) mg/L;
- (ii) Exceeds a total suspended solids concentration of two hundred-fifty (250 mg); or
- (iii) Exceeds a COD concentration of four hundred-fifty (450) mg/L.

(b) Computation of Surcharge

For those users with discharges exceeding a COD concentration of four hundred-fifty (450) mg/L, the surcharge shall be based on COD in lieu of BOD. Computations of surcharges shall be based on the formulas below. The surcharges for individual BOD or COD and

(i) BOD surcharge

$$S_{\text{BOD}} = V \times 8.34 (A[\text{BOD} - 250])$$

(ii) TSS surcharge

$$S_{\text{TSS}} = V \times 8.34 (B[\text{TSS} - 250])$$

(iii) COD surcharge

$$S_{\text{COD}} = V \times 8.34 (C[\text{COD} - 450])$$

where:

S - Sum of surcharges in dollars that will appear on the user's monthly bill.

V - Monthly average volume of non-domestic discharge in millions of gallons whichever is the least of the following volumes: (1) total monthly water consumption during the billing period, (2) the average water consumption for the billing periods of December, January, and February of each fiscal year, or; (3) the total estimated or measured non-domestic discharge as determined by methods specified in the user's permit.

8.34 - Conversion factor for units of measure in surcharge equations.

A - cost per pound of BOD

B - cost per pound of TSS

C - cost per pound of COD

Fees may be found at Chapter 10 Section 10.202 of the City of Sunflower Code of Ordinances 1990 edition.

BOD- BOD concentration in mg/L. For more than one non-domestic discharge, this shall be the flow-weighted concentration.

TSS- total suspended solids concentration mg/L. For more than on non-domestic discharge, this shall be the flow-weighted concentration.

COD- COD concentration in mg/L. For more than one non-domestic discharge, this shall be the flow-weighted concentration.

250- normal daily average BOD and TSS concentration in mg/L.

450- normal daily average COD in mg/L.

(c) Sampling and Analysis

The City shall sample for BOD, TSS, and COD. The time of sampling shall be at the sole discretion of the Control Authority. The Control Authority may select an independent contractor to conduct the sampling and/or analyses.

(d) Period of Surcharge

If analyses for BOD, TSS, or COD shows that a surcharge is applicable, the surcharge shall be retroactive for two (2) monthly billing periods and shall continue for four (4) monthly billing periods.

(e) Costs of Analyses

When analyses show that a surcharge shall be applied, a fee of \$50 shall be added to a user's bill to cover the sampling, handling, and laboratory analyses. When analyses show that a surcharge shall not be applied, then this fee shall not be added to the user's bill.

(3) Fees Shall be Periodically Reviewed

In order to ensure an equitable cost recovery system, the Control Authority shall periodically review the fees and adjust them as appropriate.

10.413 CONFIDENTIALITY

Any information provided by a user that is claimed as confidential by the user shall be treated in accordance with the confidentiality requirements of the General Pretreatment Regulations. All other information which is submitted by the user to the City shall be available to the public at least to the extent provided by Title 40 Code of Federal Regulations, 403.14.

10.414 RIGHT OF REVISION

The City shall have the right to revise the Pretreatment Requirements to ensure compliance with federal, state, or local requirements.

10.415 PUBLIC PARTICIPATION

The City shall comply with the public participation requirements of Title 40 Code of Federal Regulations, 403.8(f)(2)(vii) in the enforcement of these Pretreatment Requirements.

SECTION 10.500 CREATION OF MUNICIPAL UTILITY DISTRICTS

Each request or petition to the city for its written consent for the creation of a municipal utility district shall be accompanied by a fee of five thousand dollars (\$5,000.00) which shall be paid to the city to defray the expense of reviewing and responding to said request or petition.

SECTION 10.600 ENVIRONMENTAL SERVICES FEES

Fees established in this Section shall be periodically reviewed and adjusted to ensure an equitable cost recovery system.

This Section reserved for future use.

This Section reserved for future use.

ANALYTICAL AND SAMPLING FEES

Applicability

The fees described herein do not apply to any sampling event or analytical work initiated by the City for the purposes of its own routine testing and monitoring.

Analytical Fees

Analytical Fees for Wastewater

Biochemical Oxygen Demand (BOD) \$15.00per sample

Total Suspended Solids (TSS) \$15.00per sample

Chemical Oxygen Demand (COD) \$15.00per sample

Water Bacteriological Fees

Fees for bacteriological analysis shall be \$10.00 per water sample.

Sampling Fees

The sampling fee for wastewater discharge is \$75.00 per sampling event.

The wastewater discharge sampling event consists of a twenty four hour composite sample taken by automatic sampler. The scheduling of this service is subject to approval and availability of the appropriate Public Works personnel.

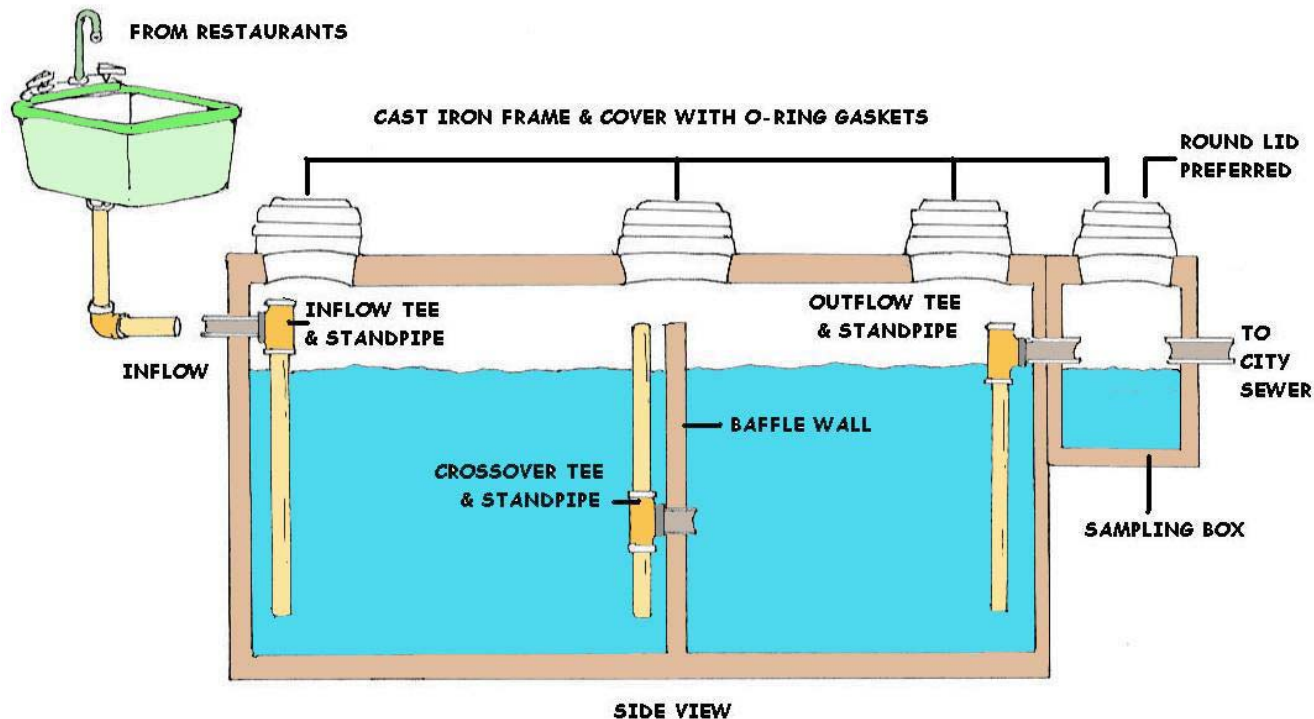
Payment of Fees

Fees for analytical or sampling work requested by a water or wastewater customer of the City shall be billed to the customer on the monthly utility bill. Fees for analytical sampling work requested by persons or entities that are not water or wastewater customers of the City must be paid in advance at the Public Works office. Requests for analytical or sampling work must be accompanied by the appropriate paper work and evidence of payment, if applicable.





Grease Disposal Program



Did you know that cooking grease is one of the major causes of residential sewer main clogs resulting in sewer spills? Cooking grease coats pipelines much like fatty foods clog human arteries. The grease clings to the insides of the pipe, eventually causing blockage and potential sewer spills. By following a few simple steps, you can help prevent costly sewer spills in the future.

- * All cooking oil (this includes salad oil, frying oil and bacon fat) should be poured into an old milk carton, frozen juice container, or other non-recyclable package, and disposed of in the garbage.
- * Dishes and pots that are coated with greasy leftovers should be wiped clean with a disposable towel prior to washing or placing in the dishwasher.
- * Instead of placing fat trimmings from meat down the garbage disposal, place them in a trash can.



Vactor

Grease Trap

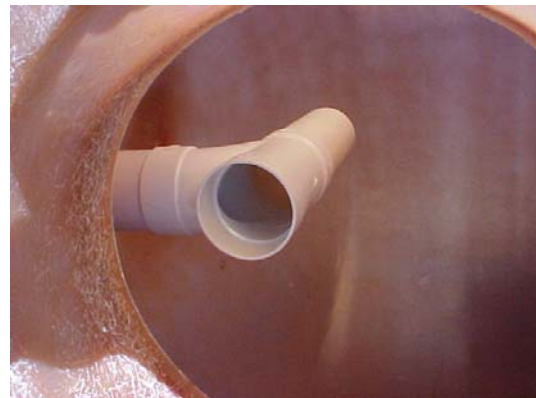
The trap prevents excess grease from getting into the sewer system from existing plumbing lines within facilities. Traps are small and are usually installed inside a facility. Generally, they range in size from 20 gallons per minute (gpm) to 50 gpm.



Infloor grease trap being removed and replaced with a grease interceptor.

Grease Interceptors

High-volume or new establishments use grease interceptors which are larger than the traps and are installed underground, outside of a facility. Grease is actually "*intercepted*" in these concrete tanks before it reaches the City sewer main. Grease interceptors should be accessible by three manhole covers, and a sample box. Interceptors and traps cause the flow of water to slow down, allowing the grease to naturally float to the top of the tank for easy removal.



New fiberglass three compartment grease interceptor. You will need to fill the interceptor with water before connecting it to the sewer main.

Plan Checks and Inspections

All plans for new commercial food establishments (including new construction remodels and retrofits) should receive a plan review from the POTW. This review assures that appropriate grease-removal equipment is installed during construction.

Grease Blockages

Shortly after sewer-spills caused by grease are reported, POTW inspectors investigate facilities within the immediate area. A determination is made as to which commercial facilities contributed to the blockage, and more in-depth inspections are conducted at those facilities. Where appropriate, additional requirements and/or procedures are put in place.

When requirements are made for additional grease-removal equipment, the facility is given a due date to comply. A Notice of Violation, with an administrative fee, is issued once a facility has passed its final due date. Administrative hearings, permit revocation, and ultimately, termination of sewer service may occur for those facilities that remain out of compliance.

Regular Grease Inspection

Regular inspection and maintenance is essential to the proper operation of a grease removal device. The local ordinance should require a minimum cleaning frequency of once every six months. However, that frequency will increase depending on the capacity of the device, the amount of grease in the wastewater, and the degree to which the facility has contributed to blockages in the past.

Regular cleaning at the appropriate interval is necessary to maintain the rated efficiency of the device. Equipment that is not regularly maintained puts the food service facility at risk of violating the sewer use ordinance, and this may not be known until an overflow and violation have occurred.

Most POTWs suggest businesses start with quarterly cleanings that should be done when 75 percent of the retention capacity of the unit is full of accumulated grease. A large measuring stick and/or a clear piece of conduit may be used to determine the depth of the grease accumulation.

You should contract with a licensed grease hauler to remove it from your premises for appropriate disposal.

Choosing a Grease Hauler

When selecting a grease hauler, be aware that services and prices can vary. Minimum services should include:

- Complete pumping and cleaning of the interceptor and sample box, rather than just skimming the grease layer.
- Deodorizing and thorough cleaning of affected areas, as necessary.
- Disposal/reclamation at an approved location.
- Notes concerning the condition of the interceptor.
- Complete pumping and cleaning record.

You and your hauler should agree on an adequate cleaning frequency to avoid blockage of the line.

Recyclable grease storage

Waste grease from a kitchen is recyclable for use in making soap, animal feed, etc. Grease from a grease trap or interceptor may not be reused in this way.

For recyclable grease, some POTWs recommend that all facilities have waste grease containers, with tight fitting lids, that are either secondarily contained or kept in a bermed area to protect floor drains and storm drain inlets from spills.

Keeping up-to-date records

Careful record keeping is one of the best ways to ensure that your grease removal device is being cleaned and maintained on a regular basis. City codes and ordinances require records be maintained for a minimum of three to five years.

Other types of devices

A grease trap may be approved in lieu of an interceptor for full service food service facilities only in very limited circumstances when space is not available.

Grease traps may also be approved by the Industrial Pretreatment Program for facilities such as delicatessens and small bakeries that produce small quantities of oil, grease, or fat . Refer to the International Plumbing Code for requirements related to grease traps such as installation of flow-control devices, flow rates, and other structural requirements.

Please Note: flow restrictors are required for grease traps because they increase retention time and efficiency. Automatic grease skimming devices collect small volumes of water and remove grease into a side container at preset times each day.

Usually, special approval from the Industrial Pretreatment Staff or the POTW is required to install one of these devices in lieu of a grease interceptor.

Magic Grease “Bugs” and Bacterial Additives

Manufacturers of bacterial additives claim that their products can remove grease and enhance the performance of grease traps and interceptors . Such additives cannot be substituted for a grease removal device and regular inspection and maintenance. If you decide to use an additive, make sure the product you select is not an emulsifier, which simply keeps grease in suspension temporarily and allows it to flow to the sewer system.

Obtaining Necessary Permits

- Building departments prefer in-ground installations that drain by gravity to the sanitary sewer. Avoid pumps and other mechanical devices in your connection to the sewer if possible.
- Size your interceptor or grease trap in accordance with the International Plumbing Code, IAPMO or local ordinance.

Combined Sewer Overflows (CSOs)

Combined sewer systems are designed to collect both sanitary wastewater and storm water runoff. During dry weather, combined sewers carry sanitary waste to a POTW. During wet weather, the combined sanitary waste and storm water can overflow and discharge untreated wastewater directly to a surface water through a combined sewer overflow (**CSO**).

In 1994, the EPA published a CSO Control Policy (59 FR 18688). CSOs are regulated as point sources, and require NPDES permits.

The CSO Control Policy includes Nine Minimum Controls (**NMC**) for CSO management, which are requirements for any CSO NPDES Permit:

- Proper operation and regular maintenance programs for the sewer system and the CSOs;

- Maximum use of the collection system for storage;

- Review and modification of pretreatment requirements to ensure that CSO impacts are minimized;

- Maximization of flow to the POTW for treatment;

- Prohibition of CSOs during dry weather;

- Control of solid and floatable materials in CSOs;

- Establishment of pollution prevention programs;

- Public notification to ensure that the public receives adequate notification of CSO occurrences and CSO impacts;

- Monitoring to effectively characterize CSO impacts and the efficacy of CSO controls.

Development of a Long Term Control Plan (**LTCP**) is also required for management of CSOs. For more information, visit the EPA Wet Weather information page, which includes a graphic representation of Urban Wet Weather Flows.



A Vactor clearing a Manhole.



The EPA's National Pollutant Discharge Elimination System (**NPDES**) stormwater discharge permit program was developed to regulate the runoff of stormwater from various types of facilities. Covered facilities are required to obtain NPDES permits, submit management plans to reduce runoff, and disconnect illegal connections to storm drains.

A permittee is required to develop a pollution prevention plan that details the best management practices the facility will use to ensure that the stormwater from its site does not impact surface waters.

The permittee must also develop a training program that covers such topics as spill prevention and response, good housekeeping, and material management practices so that employees are aware of the goals of the stormwater pollution prevention plan (**SWPPP**) and have an overall understanding of its provisions.

Collection Systems O&M Section

Sewer Cleaning and Inspection

As sewer system networks age, the risk of deterioration, blockages, and collapses becomes a major concern. As a result, municipalities worldwide are taking proactive measures to improve performance levels of their sewer systems.

Cleaning and inspecting sewer lines are essential to maintaining a properly functioning system; these activities further a community's reinvestment into its wastewater infrastructure.

Inspection Techniques

Inspection programs are required to determine current sewer conditions and to aid in planning a maintenance strategy. Ideally, sewer line inspections need to take place during low flow conditions. If the flow conditions can potentially overtop the camera, then the inspection should be performed during low flow times between midnight and 5 AM, or the sewer lines can be temporarily plugged to reduce the flow. Most sewer lines are inspected using one or more of the following techniques:

- Closed-circuit television (CCTV).
- Cameras.
- Visual inspection.
- Lamping inspection.

Television (TV) inspections are the most frequently used, most cost efficient in the long term, and most effective method to inspect the internal condition of a sewer. CCTV inspections are recommended for sewer lines with diameters of 0.1-1.2 m (4 - 48 inches.) The CCTV camera must be assembled to keep the lens as close as possible to the center of the pipe. In larger sewers, the camera and lights are attached to a raft, which is floated through the sewer from one manhole to the next. To see details of the sewer walls, the camera and lights swivel both vertically and horizontally.

In smaller sewers, the cable and camera are attached to a sled, to which a parachute or droge is attached and floated from one manhole to the next. Documentation of inspections is very critical to a successful operation and maintenance (O&M) program. CCTV inspections produce a video record of the inspection that can be used for future reference. In larger sewers where the surface access points are more than 300 m (1000 linear feet) apart, camera inspections are commonly performed. This technique involves a raft-mounted film camera and strobe light. This method requires less power than the CCTV, so the power cable is smaller and more manageable. Inspections using a camera are documented on Polaroid still photographs that are referenced in a log book according to date, time, and location.

Visual inspections are vital in fully understanding the condition of a sewer system. Visual inspections of manholes and pipelines are comprised of surface and internal inspections. Operators should pay specific attention to sunken areas in the groundcover above a sewer line and areas with ponding water. In addition, inspectors should thoroughly check the physical conditions of stream crossings, the conditions of manhole frames and covers or any exposed brickwork, and the visibility of manholes and other structures. For large sewer lines, a walk-through or internal inspection is recommended. This inspection requires the operator to enter a manhole, the channel, and the pipeline, and assess the condition of the manhole frame, cover, and chimney, and the sewer walls above the flow line.

When entering a manhole or sewer line, it is very important to observe the latest Occupational Safety and Health Administration confined space regulations. If entering the manhole is not feasible, mirrors can be used. Mirrors are usually placed at two adjacent manholes to reflect the interior of the sewer line. Lamping inspections are commonly used in low priority pipes, which tend to be pipes that are less than 20 years old.

Lamping is also commonly used on projects where funds are extremely limited. In the lamping technique, a camera is inserted and lowered into a maintenance hole and then positioned at the center of the junction of a manhole frame and the sewer. Visual images of the pipe interior are then recorded with the camera. Several specialized inspection techniques have been recently developed worldwide. Light-line based and sonar-based equipment that measures the internal cross-sectional profile of sewer systems.

Sonar technology could be very useful in inspecting depressed sewers (inverted siphons), where the pipe is continually full of water under pressure. Melbourne Water and CSIRO Division of Manufacturing Technology have introduced a new technology called PIRAT, which consists of an in-pipe vehicle with a laser scanner. This instrument is capable of making a quantitative and automatic assessment of sewer conditions. The geometric data that is gathered is then used to recognize, identify, and rate defects found in the sewer lines.

Cleaning Techniques

To maintain its proper function, a sewer system needs a cleaning schedule. There are several traditional cleaning techniques used to clear blockages and to act as preventative maintenance tools. When cleaning sewer lines, local communities need to be aware of EPA regulations on solid and hazardous waste as defined in 40 CFR 261. In order to comply with state guidelines on testing and disposal of hazardous waste, check with the local authorities.

Hydraulic cleaning developments have also been emerging on the international frontier. France and Germany have developed several innovative flushing systems using a 'dam break' concept.

France has developed a flushing system called the Hydrass. The design of the Hydrass consists of a gate that pivots on a hinge to a near horizontal position. As the gate opens and releases a flow, a flush wave is generated that subsequently washes out any deposited sediments. Germany has also developed a similar system called GNA Hydrosel®. This is a flushing system that requires no electricity, no maintenance and no fresh water. The Hydrosel® consists of a hydraulically-operated gate and a concrete wall section constructed to store the flush water. This system can be installed into a large diameter sewer.

There appears to be no limit on the flushing length, as more flush water may be stored without incurring any additional construction or operating costs. Another example of such a technology is seen in the Brussels Sewer System. A wagon with a flushing vane physically moves along the sewer and disturbs the sediments so that they are transported with the sewer flow.

Although all of these methods have proven effective in maintaining sewer systems, the ideal method of reducing and controlling the materials found in sewer lines is education and pollution prevention. The public needs to be informed that common household substances such as grease and oil need to be disposed in the garbage in closed containers, and not into the sewer lines. This approach will not only minimize a homeowner's plumbing problems, but will also help keep the sewer lines clear.

In recent years, new methodologies and accelerated programs have been developed to take advantage of the information obtained from sewer line maintenance operations. Such programs incorporate information gathered from various maintenance activities with basic sewer evaluations to create a system that can remedy and prevent future malfunctions and failures more effectively and efficiently. Some cities have attempted to establish a program that would optimize existing maintenance activities to reduce customer complaints, sanitary sewer overflows, time and money spent on sewer blockages, and other reactive maintenance activities. Their plan is based on maintenance frequencies, system performance, and maintenance costs over a period of time. This plan was developed using Geographical Information System (GIS) and historical data to show areas of complaints, back-ups, and general maintenance information for the area.

Technology Uses and Applications

Mechanical

Rodding

- Uses an engine and a drive unit with continuous rods or sectional rods.
- As blades rotate they break up grease deposits, cut roots, and loosen debris.
- Rodders also help thread the cables used for TV inspections and bucket machines.
- Most effective in lines up to 12 inches in diameter.

Bucket Machine

- Cylindrical device, closed on one end with 2 opposing hinged jaws at the other.
- Jaws open and scrape off the material and deposit it in the bucket.
- Partially removes large deposits of silt, sand, gravel, and some types of solid waste.

Hydraulic

Balling

- A threaded rubber cleaning ball that spins and scrubs the pipe interior as flow increases in the sewer line.
- Removes deposits of settled inorganic material and grease build-up.
- Most effective in sewers ranging in size from 5-24 inches.

Flushing

- Introduces a heavy flow of water into the line at a manhole.
- Removes floatables and some sand and grit.
- Most effective when used in combination with other mechanical operations, such as rodding or bucket machine cleaning.

Jetting

- Directs high velocities of water against pipe walls.
- Removes debris and grease build-up, clears blockages, and cuts roots within small diameter pipes.
- Efficient for routine cleaning of small diameter, low flow sewers.

Technology Applications

Scooter

- Round, rubber-rimmed, hinged metal shield that is mounted on a steel framework on small wheels. The shield works as a plug to build a head of water.
- Scours the inner walls of the pipe lines.
- Effective in removing heavy debris and cleaning grease from line.

Kites, Bags, and Poly Pigs

- Similar in function to the ball.
- Rigid rims on bag and kite induce a scouring action.
- Effective in moving accumulations of decayed debris and grease downstream.

Silt Traps

- Collect sediments at convenient locations.
- Must be emptied on a regular basis as part of the maintenance program.

Grease Traps and Sand/Oil Interceptors

- The ultimate solution to grease build-up is to trap and remove it.
- These devices are required by some uniform building codes and/or sewer-use ordinances. Typically sand/oil interceptors are required for automotive business discharge.
- Need to be thoroughly cleaned to function properly.

- Cleaning frequency varies from twice a month to once every 6 months, depending on the amount of grease in the discharge.
- Need to educate restaurant and automobile businesses about the need to maintain these traps.

Chemicals

Before using these chemicals review the Material Safety Data Sheets (MSDS) and consult the local authorities on the proper use of chemicals as per local ordinance and the proper disposal of the chemicals used in the operation. If assistance or guidance is needed regarding the application of certain chemicals, contact the U.S. EPA or state water pollution control agency.

- Used to control roots, grease, odors (H₂S gas), concrete corrosion, rodents and insects.
- *Root Control* - longer lasting effects than power rodder (approximately 2-5 years).
- *H₂S gas* - some common chemicals used are chlorine (Cl₂), hydrogen peroxide (H₂O₂), pure oxygen (O₂), air, lime (Ca(OH)₂), sodium hydroxide (NaOH), and iron salts.
- *Grease and soap problems* - some common chemicals used are bioacids, digester, enzymes, bacteria cultures, catalysts, caustics, hydroxides, and neutralizers.

Source: Information provided by Arbour and Kerri, 1997 and Sharon, 1989.

Most cities that take advantage of this are able to determine that as the maintenance frequency increased, there was an increase in system performance. Garland recommended 70 inspections and maintenance activities for every 30 cleanings. Inspections are considered more important because they help define and prevent future problems.

A study performed by the American Society of Civil Engineers reports that the most important maintenance activities are cleaning and CCTV inspections. A maintenance plan attempts to develop a strategy and priority for maintaining pipes based on several of the following factors:

- *Problems-* frequency and location; 80 percent of problems occur in 25 percent of the system (Hardin and Messer, 1997).
- *Age-* older systems have a greater risk of deterioration than newly constructed sewers.
- *Construction material-* pipes constructed of materials that are susceptible to corrosion have a greater potential of deterioration and potential collapse. Non-reinforced concrete pipes, brick pipes, and asbestos cement pipes are examples of pipes susceptible to corrosion.
- *Pipe diameter/volume conveyed-* pipes that carry larger volumes take precedence over pipes that carry a smaller volume.
- *Location-* pipes located on shallow slopes or in flood prone areas have a higher priority.
- *Force main vs. gravity-* force mains have a higher priority than gravity, size for size, due to the complexity of the cleaning and repairs.
- *Subsurface conditions-* depth to groundwater, depth to bedrock, soil properties (classification, strength, porosity, compressibility, frost susceptibility, erodibility, and pH).
- *Corrosion potential-* Hydrogen Sulfide (H₂S) is responsible for corroding sewers, structures, and equipment used in wastewater collection systems. The interior conditions of the pipes need to be monitored and treatment needs to be implemented to prevent the growth of slime bacteria and the production of H₂S gases.

Activity Average (% of system/year)

Cleaning 29.9

Root removal 2.9

Manhole inspection 19.8

CCTV inspection 6.8

Smoke testing 7.8

Source: ASCE, 1998.

Advantages and Disadvantages

The primary benefit of implementing a sewer maintenance program is the reduction of SSOs, basement backups, and other releases of wastewater from the collection system due to substandard sewer conditions. Improper handling of instruments and chemicals used in inspecting and maintaining sewer lines may cause environmental harm.

Examples include:

- Improperly disposing of collected materials and chemicals from cleaning operations.
- Improperly handling chemical powdered dyes.
- Inadequately maintaining inspection devices.

Visual Inspection

In smaller sewers, the scope of problems detected is minimal because the only portion of the sewer that can be seen in detail is near the manhole. Therefore, any definitive information on cracks or other structural problems is unlikely. However, this method does provide information needed to make decisions on rehabilitation.

Camera Inspection

When performing a camera inspection in a large diameter sewer, the inspection crew is essentially taking photographs haphazardly, and as a result, the photographs tend to be less comprehensive.

Closed Circuit Television (CCTV)

This method requires late night inspection and as a result the TV operators are vulnerable to lapses in concentration. CCTV inspections are also expensive and time consuming. The video camera does not fit into the pipe and during the inspection it remains only in the maintenance hole.

Lamping Inspection

As a result, only the first 10 feet of the pipe can be viewed or inspected using this method.

Source: Water Pollution Control Federation, 1989. Some instruments have a tendency to become coated with petroleum based residues and if not handled properly they can become a fire hazard.

The following case study provide additional case study data for sewer cleaning methods.

Fairfax County, Virginia

The Fairfax County Sanitary Sewer System comprises over 3000 miles of sewer lines. As is the case with its sewer rehabilitation program, the county's sewer maintenance program also focuses on inspection and cleaning of sanitary sewers, especially in older areas of the system. Reorganization and streamlining of the sewer maintenance program, coupled with a renewed emphasis on increasing productivity, has resulted in very significant reductions in sewer backups and overflows during the past few years.

1998, there were a total of 49 such incidents including 25 sewer backups and 24 sewer overflows. The sewer maintenance program consists of visual inspections, scheduled sewer cleanings based on maintenance history, unscheduled sewer cleanings as determined by visual or closed circuit television inspections, and follow-up practices to determine the cause of backups and overflows.

Visual inspections are carried out by using a mirror attached to a pole; however, use of portable cameras has been recently introduced to enhance the effectiveness of visual inspections. Older areas of the sewer system are inspected every two years; whereas, the inspection of relatively new areas may be completed in 3 to 4 years. Cleaning is an important part of pipe maintenance.

Sewer line cleaning is prioritized based on the age of the pipe and the frequency of the problems within it. The county uses rodding and pressurized cleaning methods to maintain the pipes.

Bucket machines are rarely used because cleaning by this method tends to be time consuming. The county uses mechanical, rather than chemical, methods to remove grease and roots. Introducing chemicals into the cleaning program requires hiring an expert crew, adopting a new program, and instituting a detention time to ensure the chemicals' effectiveness.

Record keeping is also vital to the success of such a maintenance program. The county has started tracking the number of times their sewer lines were inspected and cleaned and the number of overflows and backups a sewer line experienced. This information has helped the county re-prioritize sewer line maintenance and adapt a more appropriate time schedule for cleaning and inspecting the sewer lines.

Cleaning Method Limitations

Balling, Jetting, Scooter: In general, these methods are only successful when necessary water pressure or head is maintained without flooding basements or houses at low elevations. Jetting - The main limitation of this technique is that cautions need to be used in areas with basement fixtures and in steep-grade hill areas.

Balling - Balling cannot be used effectively in pipes with bad offset joints or protruding service connections because the ball can become distorted.

Scooter - When cleaning larger lines, the manholes need to be designed to a larger size in order to receive and retrieve the equipment. Otherwise, the scooter needs to be assembled in the manhole. Caution also needs to be used in areas with basement fixtures and in steep-grade hill areas.

Bucket Machine

This device has been known to damage sewers. The bucket machine cannot be used when the line is completely plugged because this prevents the cable from being threaded from one manhole to the next. Set-up of this equipment is time-consuming.

Flushing This method is not very effective in removing heavy solids. Flushing does not remedy this problem because it only achieves temporary movement of debris from one section to another in the system.

High Velocity Cleaner

The efficiency and effectiveness of removing debris by this method decreases as the cross-sectional areas of the pipe increase. Backups into residences have been known to occur when this method has been used by inexperienced operators. Even experienced operators require extra time to clear pipes of roots and grease.

Kite or Bag When using this method, use caution in locations with basement fixtures and steep-grade hill areas.

Rodding Continuous rods are harder to retrieve and repair if broken and they are not useful in lines with a diameter of greater than 300 mm (0.984 feet) because the rods have a tendency to coil and bend. This device also does not effectively remove sand or grit, but may only loosen the material to be flushed out at a later time. Source: U.S. EPA, 1993.

Limitations of Cleaning Methods

- Sewer Cleaning and Stoppage Section- this section responds to customer complaints, pinpoints problems within the lines, and clears all blockages.
- TV Section- this section locates defects and building sewer connections (also referred to as taps) within the system.
- Preventive Maintenance Section- this section cleans and inspects the lines and also provides for Quality Assurance and Quality Control (QA/QC).

Most of collection inspections use CCTV system. However, a large percent of the lines in the worst and oldest sections of the system are inspected visually. Visual inspections are also used in the most recently installed lines and manholes. The collection system will normally utilize a variety of cleaning methods including jetting, high velocity cleaning, rodding, bucket machining, and using stop trucks (sectional rods with an attached motor). As part of a preventive maintenance approach, most collection system operators also have been using combination trucks with both flush and vacuum systems. To control roots, most collection system operators use a vapor rooter eradication system which can ensure that no roots return to the line for up to five years. The cleaning and inspection crews will usually consist of two members to operate each of the combination trucks and TV trucks.

Collection Systems, Lift Stations

Wastewater lift stations are facilities designed to move wastewater from lower to higher elevation through pipes. Key elements of lift stations include a wastewater receiving well (wet-well), often equipped with a screen or grinding to remove coarse materials; pumps and piping with associated valves; motors; a power supply system; an equipment control and alarm system; and an odor control system and ventilation system.

Lift station equipment and systems are often installed in an enclosed structure. They can be constructed on-site (custom-designed) or prefabricated. Lift station capacities range from 20 gallons per minute to more than 100,000 gallons per minute. Pre-fabricated lift stations generally have capacities of up to 10,000 gallons per minute.

Centrifugal pumps are commonly used in lift stations. A trapped air column, or bubbler system, that senses pressure and level is commonly used for pump station control. Other control alternatives include electrodes placed at cut-off levels, floats, mechanical clutches, and floating mercury switches. A more sophisticated control operation involves the use of variable speed drives. Lift stations are typically provided with equipment for easy pump removal. Floor access hatches or openings above the pump room and an overhead monorail beam, bridge crane, or portable hoist are commonly used.

The two most common types of lift stations are the dry-pit or dry-well and submersible lift stations. In dry-well lift stations, pumps and valves are housed in a pump room (dry pit or dry-well), that is easily accessible. The wet-well is a separate chamber attached or located adjacent to the dry-well (pump room) structure.

Submersible lift stations do not have a separate pump room; the lift station header piping, associated valves, and flow meters are located in a separate dry vault at grade for easy access. Submersible lift stations include sealed pumps that operate submerged in the wet-well. These are removed to the surface periodically and reinstalled using guide rails and a hoist. A key advantage of dry-well lift stations is that they allow easy access for routine visual inspection and maintenance. In general, they are easier to repair than submersible pumps. An advantage of submersible lift stations is that they typically cost less than dry-well stations and operate without frequent pump maintenance.

Submersible lift stations do not usually include large aboveground structures and tend to blend in with their surrounding environment in residential areas. They require less space and are easier and less expensive to construct for wastewater flow capacities of 10,000 gallons per minute or less.

Applicability

Lift stations are used to move wastewater from lower to higher elevation, particularly where the elevation of the source is not sufficient for gravity flow and/or when the use of gravity conveyance will result in excessive excavation depths and high sewer construction costs.

Current Status

Lift stations are widely used in wastewater conveyance systems. Dry-well lift stations have been used in the industry for many years. However, the current industry-wide trend is to replace drywell lift stations of small and medium size (typically less than 6,350 gallons per minute) with submersible lift stations mainly because of lower costs, a smaller footprint, and simplified operation and maintenance. Variable speed pumping is often used to optimize pump performance and minimize power use. Several types of variable-speed pumping equipment are available, including variable voltage and frequency drives, eddy current couplings, and mechanical variable-speed drives.

Variable-speed pumping can reduce the size and cost of the wetwell and allows the pumps to operate at maximum efficiency under a variety of flow conditions.

Because variable-speed pumping allows lift station discharge to match inflow, only nominal wet-well storage volume is required and the well water level is maintained at a near constant elevation. Variable-speed pumping may allow a given flow range to be achieved with fewer pumps than a constant-speed alternative.

Variable-speed stations also minimize the number of pump starts and stops, reducing mechanical wear. Although there is significant energy saving potential for stations with large friction losses, it may not justify the additional capital costs unless the cost of power is relatively high. Variable speed equipment also requires more room within the lift station and may produce more noise and heat than constant speed pumps.

Lift stations are complex facilities with many auxiliary systems. Therefore, they are less reliable than gravity wastewater conveyance. However, lift station reliability can be significantly improved by providing stand-by equipment (pumps and controls) and emergency power supply systems. In addition, lift station reliability is improved by using non-clog pumps suitable for the particular wastewater quality and by applying emergency alarm and automatic control systems.

Advantages

Lift stations are used to reduce the capital cost of sewer system construction. When gravity sewers are installed in trenches deeper than 10 feet, the cost of sewer line installation increases significantly because of the more complex and costly excavation equipment and trench shoring techniques required. The size of the gravity sewer lines is dependent on the minimum pipe slope and flow. Pumping wastewater can convey the same flow using smaller pipeline size at shallower depth, and thereby, reducing pipeline costs.

Disadvantages

Compared to sewer lines where gravity drives wastewater flow, lift stations require a source of electric power. If the power supply is interrupted, flow conveyance is discontinued and can result in flooding upstream of the lift station. It can also interrupt the normal operation of the downstream wastewater conveyance and treatment facilities. This limitation is typically addressed by providing an emergency power supply.

Key disadvantages of lift stations include the high cost to construct and maintain and the potential for odors and noise. Lift stations also require a significant amount of power, are sometimes expensive to upgrade, and may create public concerns and negative public reaction. The low cost of gravity wastewater conveyance and the higher costs of building, operating, and maintaining lift stations means that wastewater pumping should be avoided, if possible and technically feasible.

Wastewater pumping can be eliminated or reduced by selecting alternative sewer routes or extending a gravity sewer using direction drilling or other state-of-the-art deep excavation methods. If such alternatives are viable, a cost benefit analysis can determine if a lift station is the most viable choice.

Design Criteria

Cost effective lift stations are designed to: (1) match pump capacity, type, and configuration with wastewater quantity and quality; (2) provide reliable and uninterruptible operation; (3) allow for easy operation and maintenance of the installed equipment; (4) accommodate future capacity expansion; (5) avoid septic conditions and excessive release of odors in the collection system and at the lift station; (6) minimize environmental and landscape impacts on the surrounding residential and commercial developments; and (7) avoid flooding of the lift station and the surrounding areas.

Wet-well

Wet-well design depends on the type of lift station configuration (submersible or dry-well) and the type of pump controls (constant or variable speed). Wet-wells are typically designed large enough to prevent rapid pump cycling but small enough to prevent a long detention time and associated odor release.

Wet-well maximum detention time in constant speed pumps is typically 20 to 30 minutes. Use of variable frequency drives for pump speed control allows wet-well detention time reduction to 5 to 15 minutes. The minimum recommended wet-well bottom slope is to 2:1 to allow self-cleaning and minimum deposit of debris. Effective volume of the wet-well may include sewer pipelines, especially when variable speed drives are used. Wet-wells should always hold some level of sewage to minimize odor release. Bar screens or grinders are often installed in or upstream of the wet-well to minimize pump clogging problems.

Wastewater Pumps

The number of wastewater pumps and associated capacity should be selected to provide head capacity characteristics that correspond as nearly as possible to wastewater quantity fluctuations. This can be accomplished by preparing pump/pipeline system head-capacity curves showing all conditions of head (elevation of a free surface of water) and capacity under which the pumps will be required to operate.

The number of pumps to be installed in a lift station depends on the station capacity, the range of flow and the regulations. In small stations, with maximum inflows of less than 700 gallons per minute, two pumps are customarily installed, with each unit able to meet the maximum influent rate. For larger lift stations, the size and number of pumps should be selected so that the range of influent flow rates can be met without starting and stopping pumps too frequently and without excessive wet-well storage.

Depending on the system, the pumps are designed to run at a reduced rate. The pumps may also alternate to equalize wear and tear. Additional pumps may provide intermediate capacities better matched to typical daily flows. An alternative option is to provide flow flexibility with variable speed pumps.

For pump stations with high head-losses, the single pump flow approach is usually the most suitable. Parallel pumping is not as effective for such stations because two pumps operating together yield only slightly higher flows than one pump. If the peak flow is to be achieved with multiple pumps in parallel, the lift station must be equipped with at least three pumps: two duty pumps that together provide peak flow and one standby pump for emergency backup.

Parallel peak pumping is typically used in large lift stations with relatively flat system head curves. Such curves allow multiple pumps to deliver substantially more flow than a single pump. The use of multiple pumps in parallel provides more flexibility. Several types of centrifugal pumps are used in wastewater lift stations. In the straight-flow centrifugal pumps, wastewater does not change direction as it passes through the pumps and into the discharge pipe. These pumps are well suited for low-flow/high head conditions.

In angle-flow pumps, wastewater enters the impeller axially and passes through the volute casing at 90 degrees to its original direction. This type of pump is appropriate for pumping against low or moderate heads. Mixed flow pumps are most viable for pumping large quantities of wastewater at low head. In these pumps, the outside diameter of the impeller is less than an ordinary centrifugal pump, increasing flow volume.

Ventilation

Ventilation and heating are required if the lift station includes an area routinely entered by personnel. Ventilation is particularly important to prevent the collection of toxic and/or explosive gases. According to the National Fire Protection Association (NFPA) Section 820, all continuous ventilation systems should be fitted with flow detection devices connected to alarm systems to indicate ventilation system failure. Dry-well ventilation codes typically require six continuous air changes per hour or 30 intermittent air changes per hour. Wet-wells typically require 12 continuous air changes per hour or 60 intermittent air changes per hour. Motor control center (MCC) rooms should have a ventilation system adequate to provide six air changes per hour and should be air conditioned to between 13 and 32 degrees Celsius (55 to 90 degrees F). If the control room is combined with an MCC room, the temperature should not exceed 30 degrees C or 85 degrees F. All other spaces should be designed for 12 air changes per hour. The minimum temperature should be 13 degrees C (55 degrees F) whenever chemicals are stored or used.

Odor Control

Odor control is frequently required for lift stations. A relatively simple and widely used odor control alternative is minimizing wet-well turbulence. More effective options include collection of odors generated at the lift station and treating them in scrubbers or biofilters or the addition of odor control chemicals to the sewer upstream of the lift station. Chemicals typically used for odor control include chlorine, hydrogen peroxide, metal salts (ferric chloride and ferrous sulfate) oxygen, air, and potassium permanganate. Chemicals should be closely monitored to avoid affecting downstream treatment processes, such as extended aeration.

Power Supply

The reliability of power for the pump motor drives is a basic design consideration. Commonly used methods of emergency power supply include electric power feed from two independent power distribution lines; an on-site standby generator; an adequate portable generator with quick connection; a stand-by engine driven pump; ready access to a suitable portable pumping unit and appropriate connections; and availability of an adequate holding facility for wastewater storage upstream of the lift station.

Performance

The overall performance of a lift station depends on the performance of the pumps. All pumps have four common performance characteristics: capacity, head, power, and overall efficiency. Capacity (flow rate) is the quantity of liquid pumped per unit of time, typically measured as gallons per minute (gpm) or million gallons per day (mgd).

Head is the energy supplied to the wastewater per unit weight, typically expressed as feet of water. Power is the energy consumed by a pump per unit time, typically measured as kilowatt-hours. Overall efficiency is the ratio of useful hydraulic work performed to actual work input. Efficiency reflects the pump relative power losses and is usually measured as a percentage of applied power.

Pump performance curves are used to define and compare the operating characteristics of a pump and to identify the best combination of performance characteristics under which a lift station pumping system will operate under typical conditions (flows and heads). Pump systems operate at 75 to 85 percent efficiency most of the time, while overall pump efficiency depends on the type of installed pumps, their control system, and the fluctuation of influent wastewater flow.

Performance optimization strategies focus on different ways to match pump operational characteristics with system flow and head requirements. They may include the following options: adjusting system flow paths installing variable speed drives; using parallel pumps installing pumps of different sizes trimming a pump impeller; or putting a two-speed motor on one or more pumps in a lift station. Optimizing system performance may yield significant electrical energy savings.

Operation and Maintenance

Lift station operation is usually automated and does not require continuous on-site operator presence. However, frequent inspections are recommended to ensure normal functioning and to identify potential problems. Lift station inspection typically includes observation of pumps, motors and drives for unusual noise, vibration, heating and leakage, check of pump suction and discharge lines for valving arrangement and leakage, check of control panel switches for proper position, monitoring of discharge pump rates and pump speed, and monitoring of the pump suction and discharge pressure.

Weekly inspections are typically conducted, although the frequency really depends on the size of the lift station. If a lift station is equipped with grinder bar screens to remove coarse materials from the wastewater, these materials are collected in containers and disposed of to a sanitary landfill site as needed. If the lift station has a scrubber system for odor control, chemicals are supplied and replenished typically every three months. If chemicals are added for odor control ahead of the lift station, the chemical feed stations should be inspected weekly and chemicals replenished as needed.

The most labor-intensive task for lift stations is routine preventive maintenance. A well-planned maintenance program for lift station pumps prevents unnecessary equipment wear and downtime. Lift station operators must maintain an inventory of critical spare parts. The number of spare parts in the inventory depends on the critical needs of the unit, the rate at which the part normally fails, and the availability of the part. The operator should tabulate each pumping element in the system and its recommended spare parts. This information is typically available from the operation and maintenance manuals provided with the lift station.

Operating Costs

Lift station costs depend on many factors, including

- (1) wastewater quality, quantity, and projections;
- (2) zoning and land use planning of the area where the lift station will be located;
- (3) alternatives for standby power sources;
- (4) operation and maintenance needs and support;
- (5) soil properties and underground conditions;
- (6) required lift to the receiving (discharge) sewer line;
- (7) the severity of impact of accidental sewage spill upon the local area; and
- (8) the need for an odor control system.

These site and system specific factors must be examined and incorporated in preparing a lift station cost estimate.

Construction Costs

The most important factors influencing cost are the design lift station capacity and the installed pump power. Another cost factor is the lift station complexity. Factors which classify a lift station as complex include two or more of the following:

- (1) extent of excavation;
- (2) congested site and/or restricted access;
- (3) rock excavation;
- (4) extensive dewatering requirements, such as cofferdams;
- (5) site conflicts, including modification or removal of existing facilities;
- (6) special foundations, including piling;
- (7) dual power supply and on-site switch stations and emergency power generator; and
- (8) high pumping heads (design heads in excess of 200 ft).

Stormwater

Stormwater runoff is rainwater or melted snow which flows across the ground and eventually into lakes, streams, wetlands, underground water supplies, and the ocean.

The construction of pavement and buildings, and the clearing and flattening of fields increase the volume and speed of stormwater runoff. This contributes to flooding and damage to property and habitat (stormwater quantity impacts). It also contributes to lowering of water quality by increasing the flow of human pollutants such as oil, fertilizers and pesticides, and the flow of natural elements such as phosphorus, into the water (stormwater quality impacts).

Degradation of lakes, streams and wetlands has economic effects: it reduces property values, raises bills from public water utilities, raises local property tax rates, and reduces tourism and related business income.

The U.S. Environmental Protection Agency (**EPA**) estimates that 60% of the water quality problems in the nation are caused by nonpoint sources.

Stormwater runoff has quantity and quality impacts. When impervious or disturbed areas are created by construction activities and stormwater is not adequately managed, the environment may be adversely affected by: (1) changes in volume, timing, and location of the stormwater discharges, and (2) the movement of pollutants from the site to waterbodies. Stormwater runoff can cause flooding, undermine stream banks, and damage property and habitat, as well as carry contaminants that contribute to lower water quality.



Nonpoint source (NPS) pollution is water pollution that consists of contaminated runoff associated with agricultural, urban, and other sources. The term “**nonpoint source pollution**” was created under the federal Clean Water Act to distinguish it from “point source” discharges such as industrial waste water from pipes.

Nonpoint sources include many varied small sources of pollutants from activities.

Every time it rains or the snow melts, pollutants such as dirt, nutrients, bacteria, oils and heavy metals are swept off from land surfaces and carried by runoff water into surface and groundwater.

When people speak about “**stormwater quality control**”, they are talking about reducing the pollutants from nonpoint sources that are carried by stormwater into our lakes, streams, groundwater, and coastal areas.

The Clean Water Act of 1972 (passed by the United States Congress and amended by the Water Quality Act of 1987) set in motion requirements and policy measures for the Environmental Protection Agency (EPA). The EPA therewith established regulatory components for Storm Water Discharges which were levied upon associated industries and municipalities with populations over 100,000.

The goal of NPDES, through permits and plans, is to reduce to the maximum extent practical, the amount of pollution discharges from the municipal storm drainage systems. These municipal permits have several components, one being management programs. A term frequently used in this subject matter is - **Best Management Practices (BMP)**.

BMP's are schedules of activities, prohibition of practices, maintenance procedures, and other recommended management practices that may be employed for a particular purpose - Storm Water Pollution Prevention and Reduction.

Although the EPA / NPDES regulations seem complex, their goal is simple - ***"Improve water quality in waters of the United States"***.



Evidence of illegal paint and chemical dumping.

What is Nonpoint Source Pollution?

Nonpoint source (**NPS**) pollution, unlike pollution from industrial and sewage treatment plants, comes from many diffuse sources. NPS pollution is caused by rainfall or snowmelt moving over and through the ground. As the runoff moves, it picks up and carries away natural and human-made pollutants, finally depositing them into lakes, rivers, wetlands, coastal waters, and even our underground sources of drinking water.

These pollutants include:

- Excess fertilizers, herbicides, and insecticides from agricultural lands and residential areas;
- Oil, grease, and toxic chemicals from urban runoff and energy production;
- Sediment from improperly managed construction sites, crop and forest lands, and eroding streambanks;
- Salt from irrigation practices and acid drainage from abandoned mines;
- Bacteria and nutrients from livestock, pet wastes, and faulty septic systems;

Atmospheric deposition and hydromodification are also sources of nonpoint source pollution.

What are the effects of these pollutants on our waters?

States report that nonpoint source pollution is the leading remaining cause of water quality problems. The effects of nonpoint source pollutants on specific waters vary and may not always be fully assessed. However, we know that these pollutants have harmful effects on drinking water supplies, recreation, fisheries, and wildlife.

What causes nonpoint source pollution?

Nonpoint source pollution results from a wide variety of human activities on the land. Each of us can contribute to the problem without even realizing it.



Leachate from a landfill, a strange green colored water.

Leachates

Leachates are liquids that have dripped through the landfill and carry dissolved substances from the waste materials, containing such substances as heavy metals and organic decomposition products; salt; bacteria; and viruses.

Stormwater Program Requirements

Regulation: 40 CFR 122.26

Applicability

The EPA's National Pollutant Discharge Elimination System (**NPDES**) stormwater discharge permit program was developed to regulate the runoff of stormwater from various types of facilities. Covered facilities are required to obtain NPDES permits, submit management plans to reduce runoff, and disconnect illegal connections to storm drains.

A permittee is required to develop a pollution prevention plan that details the best management practices the facility will use to ensure that the stormwater from its site does not impact surface waters.

The permittee must also develop a training program that covers such topics as spill prevention and response, good housekeeping, and material management practices so that employees are aware of the goals of the stormwater pollution prevention plan (**SWPPP**) and have an overall understanding of its provisions.

Phase I of the NPDES stormwater discharge permit program regulates:

- Operators of medium and large municipal separate storm sewer systems that generally serve or are located in incorporated places and counties with populations of 100,000 or more.
- Operators of 11 categories of industrial activity—one of which is construction activity disturbing five or more acres of land—that discharge stormwater runoff to waters of the United States or into municipal separate storm sewer systems.

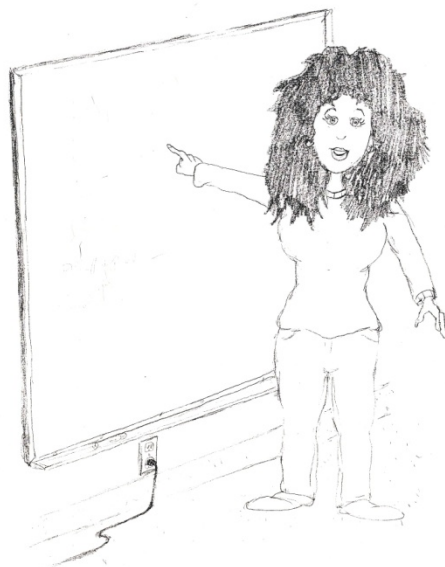
Phase II of the NPDES stormwater discharge permit program regulates two classes of stormwater dischargers on a nationwide basis:

- Operators of small municipal separate storm sewer systems located in urbanized areas.
- Operators of construction activities that disturb equal to or greater than one acre of land but less than five acres.

Training Requirements

An employee training program must inform personnel at all levels of the responsibility of the components and goals of the facility stormwater pollution prevention plan (**SWPPP**).

The training program should be an ongoing, yearly process. Facilities are required to specify a schedule for periodic training activities in the SWPPP.



Best Management Practices

Good Housekeeping

Good housekeeping practices are designed to maintain a clean and orderly work environment. Often, the most effective first step towards preventing pollution in stormwater from industrial sites simply involves using good common sense to improve the facility's basic housekeeping methods. Poor housekeeping can result in more waste being generated than necessary and an increased potential for stormwater contamination. A clean and orderly work area reduces the possibility of accidental spills caused by mishandling of chemicals and equipment and should reduce safety hazards to plant personnel. Well-maintained material and chemical storage will reduce the possibility of stormwater mixing with pollutants. Good housekeeping procedures may include:

- Improving operation and maintenance of machinery and processes.
- Implementing careful storage practices.
- Keeping an up-to-date inventory and labeling all containers.
- Scheduling routine cleanup operations.
- Training employees on good housekeeping techniques.

Preventive Maintenance

Preventive maintenance includes the regular inspection and testing of plant equipment and operational systems.

These inspections should uncover conditions, such as cracks or slow leaks, that could cause breakdowns or failures that result in discharges of chemicals to storm sewers and surface waters. The program should prevent breakdowns and failures through adjustment, repair, or replacement of equipment. An effective preventive maintenance program should include:

- Identification of equipment, systems, and facility areas that should be inspected.
- Schedule for periodic inspections or tests of such equipment and systems.
- Appropriate and timely adjustment, repair, or replacement of equipment and systems.
- Maintenance of complete records on inspections, equipment, and systems.

Examples of equipment to be inspected at a facility can include:

- Pipes
- Pumps
- Storage tanks and bins
- Pressure vessels
- Pressure release valves
- Process and material handling equipment
- Stormwater management devices (oil/water separators, catch basins, or other structural or treatment BMPs)

Spill Prevention and Response

Spills and leaks together account for one of the largest industrial sources of stormwater pollutants and are avoidable in most cases. Establishing standard operating procedures, such as safety and spill prevention procedures, along with proper employee training can reduce these accidental releases. The steps to take for spill prevention and response usually involve:

- Identify potential spill areas (such as loading and unloading areas, storage areas, process activities, dust or particulate generating processes, and waste disposal activities).
- Specify material handling procedures and storage requirements.
- Identify spill response procedures and equipment (such as spill response team; safety measures; notification of authorities; spill containment, diversion, isolation, and cleanup; and spill response equipment).

Visual Inspections

Regular visual inspections are the means to ensure that all of the elements of the SWPPP are in place and working properly. They are routine look-overs of the facility to identify conditions that may give rise to contamination of stormwater runoff with pollutants from the facility. Areas to be inspected should include:

- Areas around all equipment listed in the preventive maintenance box
- Areas where spills and leaks have occurred in the past
- Material storage areas
- Outdoor material processing areas
- Material handling areas
- Waste generation, storage, treatment, and disposal areas

All inspections must be documented, and the records must be kept with the SWPPP.

Sediment and Erosion Control

There may be certain areas on your site that, due to construction activities, steep slopes, sandy soils, or other reasons, are prone to soil erosion. Construction activities typically remove grass and other protective ground covers, resulting in the exposure of underlying soil to wind and rain. Similarly, steep slopes or sandy soils may not be capable of supporting plant life, leaving soils exposed. Because the soil surface is unprotected, dirt and sand particles are easily picked up by wind and/or washed away by rain. This process is called erosion. Erosion can be controlled or prevented with the use of certain BMPs. It is important to:

- Identify areas that, due to topography, activities, or other factors, have a high potential for significant soil erosion.
- Identify structural, vegetative, and/or stabilization measures to be used to limit erosion.

Management of Runoff

Traditional stormwater management practices can be used to direct stormwater away from areas of exposed materials or potential pollutants. These management practices can also be used to direct stormwater that contains pollutants to natural or other types of treatment locations. The potential of various sources at the facility to contribute pollutants to stormwater discharges associated with industrial activity must be considered when determining reasonable and appropriate measures.

Appropriate measures include:

- **Vegetative swales and practices**
- **Reuse of collected stormwater**
- **Inlet controls (such as oil/water separators)**
- **Snow management activities**
- **Infiltration devices**
- **Wet detention/retention devices**

Monitoring and Sampling

In addition to instituting BMPs, facilities may be required to implement a program of sampling and monitoring of their stormwater discharges. The terms of the permit will indicate the levels of sampling and monitoring required at a facility.

Stormwater Management Practices

A watershed manager needs to make careful choices about what stormwater management practices should be installed in the subwatershed to compensate for the hydrological changes caused by new and existing development. Stormwater management practices are used to delay, capture, store, treat, or infiltrate stormwater runoff. A key choice is to determine the primary stormwater objectives for a subwatershed that will govern the selection, design, and location of stormwater management practices at individual sites. While specific design objectives for stormwater management practices are often unique to each subwatershed, the general goals for stormwater management practices are often the same, and include:

maintaining groundwater quality and recharge;

reducing stormwater pollutant loads;

protecting stream channels;

preventing increased overbank flooding; and

safely conveying extreme floods.

There are numerous structural stormwater management techniques for controlling stormwater quantity and quality. These five practices can be categorized into five broad groups, including:

ponds

wetlands

infiltration

filtering systems and

grassed channels

While many advances have been made recently in innovative stormwater management designs, their ability to maintain resource quality in the absence of other watershed protection tools is limited. In fact, stormwater management practices designed or located improperly can sometimes cause more severe secondary environmental impacts than if they were not installed at all.

Basic Program Requirements

Stormwater Monitoring Program:

Objective: To obtain a baseline measurement of current water quality, discover and eliminate illicit connections to the system and, the development of watershed drainage runoff data to assist in engineering studies for future developments.

Industrial Monitoring Program:

Objective: To evaluate industrial storm water runoff locations and to perform physical site inspections and develop future pollution prevention plans.

Illicit Connection Program:

Objective: To discover and eliminate illicit connections to the storm sewer system.

In-Stream Monitoring Program:

Objective: To improve data collection and interpretation. Analysis of the monitoring sites with a full scan of pollutants as required by the NPDES permit.

Household Hazardous Waste Program:

Objective: To eliminate household hazardous waste from contaminating the storm water.

Public Educational Program:

Objective: Create a public awareness of the pollutorial risk of misusing and improper disposal of chemicals. Recycling techniques and water conservation are also parts of an overall program.



Professional Melissa Durbin teaching a group of pretreatment inspectors how to conduct an inspection.

Recycling Program

Objective: To reduce the amount of household hazardous waste disposed of improperly as well as to recover recyclable materials from the waste stream thereby reducing the demand on the landfills and improving the environment.



Young and socially responsible. Recycle.

Spill Response Program:

Objective: To prevent pollutants from entering the Storm Drainage System.

Storm Sewer Maintenance:

Objective: To prevent failure of the Storm Drainage System by performing preventative maintenance and repairs in a timely, cost-effective manner.

Street Cleaning Program:

Objective: To remove debris that has collected on the streets before it can enter the drainage system and contaminate the Storm water.

Overflow Elimination Program

Objective: To reduce the amount of overflows to the storm drain system, and increase the efficiency of expenditures by planning and coordinating all infrastructure type projects.

Clearing and Grading Permit Administration:

Objective: To allow local inspectors from the City to review construction drawings and field check compliance with such.

New and Redevelopment Program:

Objective: To reduce the discharge of pollutants to the Municipal Separate Storm Sewer System; minimize potential short and long term water quality impacts; establish inspection and enforcement procedures and appropriate control measures; develop appropriate education and training measures; and notification process for applicants of their potential responsibilities under the NPDES permitting program.

Animal Feeding Operations (AFOs) and Concentrated Animal Feeding Operations (CAFOs)

Any facility which stables, confines, feeds, or maintains animals for at least 45 days in a 12 month period, and does not sustain crops or vegetation forage growth over any portion of the facility is an animal feeding operation (**AFO**). AFOs which meet certain size and location criteria are defined as concentrated animal feeding operations (**CAFOs**). By criteria listed at 40 CFR 122 Appendix B, a CAFO is a facility which has:

more than 1,000 animal units;
between 301 and 1,000 animal units and that may or does discharge pollutants into navigable waters through a manmade conveyance, or discharges pollutants directly into waters of the United States; or
been designated a CAFO by the permitting authority on a case-by-case basis.

An animal unit (AU) is a unit of measure based on manure production of various types of livestock. One animal unit is equal to one slaughter cow, and numbers for other types of livestock are converted to AU using coefficients set forth at 40 CFR 122 Appendix B (e.g., 1 horse = 2.0 AU, 1 dairy cow = 1.4 AU, 1 swine = 0.4 AU, 1 sheep = 0.1 AU).

Facilities which are CAFOs are regulated under the point source program, and require NPDES permits. Effluent limitations guidelines for CAFOs are found at 40 CFR 412. For regulatory resources, visit the Library of EPA resources on CAFOs, which includes a downloadable "*Final Guidance on NPDES Regulations for Concentrated Animal Feeding Operations*," December 1995.



Livestock Area

The EPA and the United States Department of Agriculture have recently partnered to address water quality impacts from all animal feeding operations. On March 9, 1999 the EPA and the USDA issued the Draft Unified National Strategy for Animal Feeding Operations.

Wastewater Treatment Process

One of the most common forms of pollution control in the United States is *wastewater treatment*.

The country has a vast system of collection sewers, pumping stations, and treatment plants. Sewers collect the wastewater from homes, businesses, and many industries, and deliver it to plants for treatment. Most treatment plants were built to clean wastewater for discharge into streams or other receiving waters, or for reuse.

Years ago, when sewage was dumped into waterways, a natural process of purification began. First, the sheer volume of clean water in the stream diluted wastes. Bacteria and other small organisms in the water consumed the sewage and other organic matter, turning it into new bacterial cells; carbon dioxide and other products.

Today's higher populations and greater volume of domestic and industrial wastewater require that communities give nature a helping hand. The basic function of wastewater treatment is to speed up the natural processes by which water is purified. There are two basic stages in the treatment of wastes, *primary* and *secondary*, which are outlined here.

In the primary stage, solids are allowed to settle and removed from wastewater. The secondary stage uses biological processes to further purify wastewater. Sometimes, these stages are combined into one operation.

Primary Treatment

As sewage enters a plant for treatment, it flows through a *screen*, which removes large floating objects such as rags and sticks that might clog pipes or damage equipment. After sewage has been screened, it passes into a *grit chamber*, where cinders, sand, and small stones settle to the bottom.

A grit chamber is particularly important in communities with combined sewer systems where sand or gravel may wash into sewers along with stormwater. After screening is completed and grit has been removed, sewage still contains organic and inorganic matter along with other suspended solids.

These solids are minute particles that can be removed from sewage in a *sedimentation tank*. When the speed of the flow through one of these tanks is reduced, the suspended solids will gradually sink to the bottom, where they form a mass of solids called *raw primary biosolids* (formerly called *sludge*).



Wastewater sludge combined with newspapers to make compost

Biosolids are usually removed from tanks by pumping, after which it may be further treated for use as a fertilizer, or disposed of in a landfill or incinerated. Over the years, primary treatment alone has been unable to meet many communities' demands for higher water quality. To meet them, cities and industries normally treat to a *secondary treatment level*, and in some cases, also use advanced treatment to remove nutrients and other contaminants.

Secondary Treatment

The *secondary stage* of treatment removes about 85 percent of the organic matter in sewage by making use of the bacteria in it. The principal secondary treatment techniques used are the *trickling filter* and the *activated sludge process*.

After effluent leaves the sedimentation tank in the primary stage it flows or is pumped to a facility using one or the other of these processes. A trickling filter is simply a bed of stones from three to six feet deep through which sewage passes. More recently, interlocking pieces of corrugated plastic or other synthetic media have also been used in trickling beds. Bacteria gather and multiply on these stones until they can consume most of the organic matter. The cleaner water trickles out through pipes for further treatment. From a trickling filter, the partially treated sewage flows to another sedimentation tank to remove excess bacteria.

The trend today is towards the use of the activated sludge process instead of trickling filters. The activated sludge process speeds up the work of the bacteria by bringing air and sludge heavily laden with bacteria into close contact with sewage.

After the sewage leaves the settling tank in the primary stage, it is pumped into an *aeration tank*, where it is mixed with air and sludge loaded with bacteria and allowed to remain for several hours. During this time, the bacteria break down the organic matter into harmless by-products. The sludge now activated with additional billions of bacteria and other tiny organisms, can be used again by returning it to the aeration tank for mixing with air and new sewage. From the aeration tank, the partially treated sewage flows to another sedimentation tank for removal of excess bacteria.

To complete secondary treatment, effluent from the sedimentation tank is usually *disinfected* with chlorine before being discharged into receiving waters. Chlorine is fed into the water to kill pathogenic bacteria, and to reduce odor. Done properly, chlorination will kill more than 99 percent of the harmful bacteria in an effluent. Some municipalities now manufacture chlorine solution on site to avoid transporting and storing large amounts of chlorine, sometimes in a gaseous form. Federal law now requires the removal of excess chlorine before discharge to surface waters by a process called dechlorination. Alternatives to chlorine disinfection, such as ultraviolet light or ozone, are also being used in situations where chlorine in treated sewage effluents may be harmful to fish and other aquatic life.

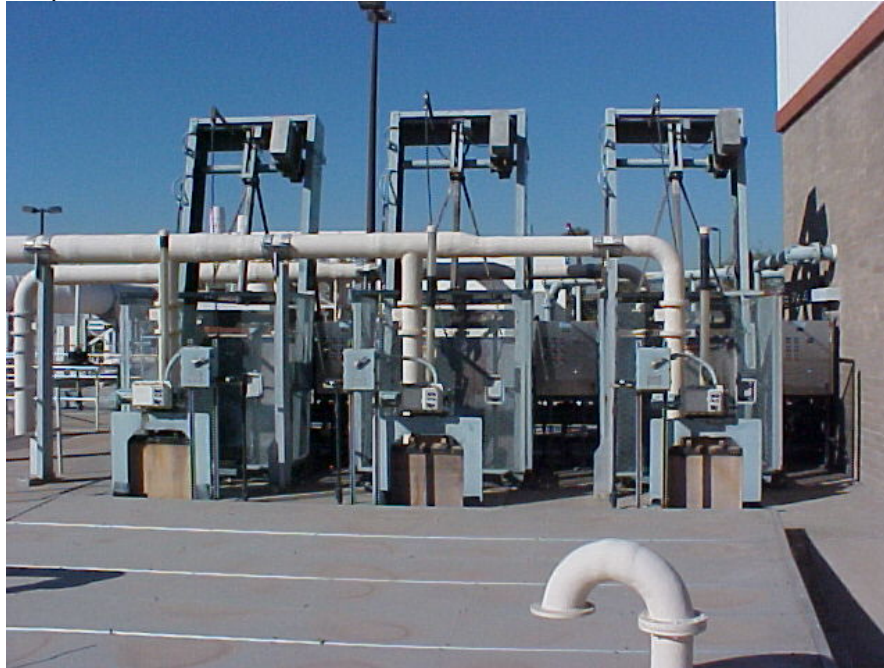
Other Treatment Options

New pollution problems have placed additional burdens on wastewater treatment systems. Today's pollutants, such as heavy metals, chemical compounds, and toxic substances, are more difficult to remove from water. Rising demands on the water supply only aggravates the problem. The increasing need to reuse water calls for better wastewater treatment. These challenges are being met through better methods of removing pollutants at treatment plants, or through prevention of pollution at the source. Pretreatment of industrial waste, for example, removes many troublesome pollutants at the beginning, not the end, of the pipeline. To return more usable water to receiving lakes and streams, new methods for removing pollutants are being developed.

Advanced waste treatment techniques in use or under development range from biological treatment capable of removing nitrogen and phosphorus to physical-chemical separation techniques such as *filtration, carbon adsorption, distillation, and reverse osmosis*. These wastewater treatment processes, alone or in combination, can achieve almost any degree of pollution control desired. Waste effluents purified by such treatment can be used for industrial, agricultural, or recreational purposes, or even drinking water supplies.

Basic Wastewater Treatment Processes

1. Plant Influent: Waste enters the treatment facility through the municipal sewer system. Raw wastewater enters the treatment facility at the beginning of the treatment plant, referred to as the "**headworks**" of the plant. The wastewater is then pumped to the wastewater treatment facility using pumps.



Preliminary treatment removes large objects from the wastewater to help prevent clogging of pipes and damaging the treatment equipment. The debris that is removed during preliminary treatment is typically hauled to a landfill for disposal.

2. Coarse Bar Screen: Metal bars collect large debris such as rags, wood, plastics, etc.

3. Grit Removal: The wastewater flows through a channel, allowing dense, inorganic material to settle on the bottom. Scrapers, hoppers and clam buckets remove the collected grits.

4. Primary Settling: The wastewater flows into large settling tanks which allow suspended solids and organic material to sink to the bottom of these tanks. The raw sludge that settles to the bottom of these tanks is removed through hoppers and sent through the digestion process.

5. Partially treated wastewater is drawn from the top of the settling tanks and in some treatment facilities, chemicals are added to remove phosphorous.

6. Aeration Basins: Large aeration basins or tanks mix the partially treated wastewater with oxygen to support bacteria which devour organic waste. The bacteria levels are managed to provide the most efficient removal process.

Aeration Basins are used in a process referred to as activated sludge. Activated sludge is a biological process where oxygen is bubbled through the water, providing aeration. The microorganisms (or "**bugs**") are suspended in the wastewater by the aeration. The mixture is known as "**mixed liquor**." The bugs break down the wastes to carbon dioxide and water.

The mixed liquor is discharged to the final clarifiers to settle out the microorganisms which are then returned to the aeration basin. Excess biosolids, which have settled out, are sent to the solids handling processes.

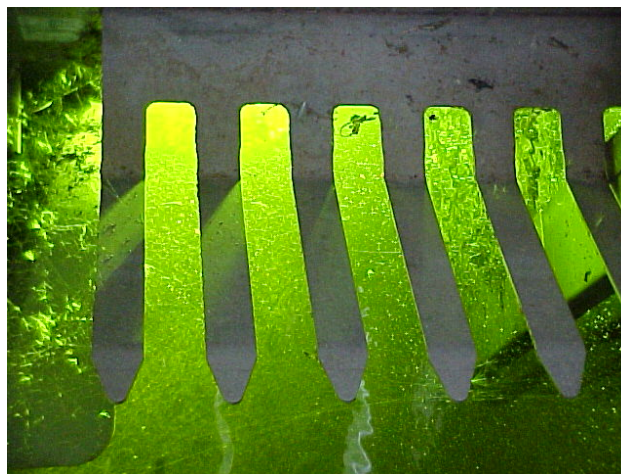
Similar to Primary Clarifiers are **Secondary Clarifiers**. These slow the speed of the wastewater to allow solids to settle out of the wastewater.

Clarifiers are used to settle out microorganisms from the activated sludge process.

Clarifiers typically have rotating arms which are used to remove scum from the surface of the water. Clarifiers are usually either round or rectangular in shape. The sludge or **biosolids** are collected at the bottom of the clarifier and sent to a digester for further treatment.

7. Final Settling: The cleanest wastewater is drawn from the top of the aeration tanks through spillways. By this point the water is already quite clear. Polymers may be added to concentrate any remaining material. Once again, suspended particles settle to the bottom and are removed by scrapers or hoppers.

8. Disinfection: The cleanest water is drawn from the surface and disinfected with chlorine, ozone or ultra-violet light to kill bacteria.



UV light generator and the actual UV light.

9. The treated water is de-chlorinated. The treated water is tested to ensure it meets the EPA standards and is returned to the original water source. Before the treated water is discharged to the receiving stream, samples are taken.

The samples are then analyzed in a laboratory. An automatic sampler will automatically take samples at designated times. The samples are then kept refrigerated in the sampler until the sample can be analyzed in the lab.



De-chlorination channel and automatic sampler.

10. Sludge from the final settling tanks is drawn from the bottom of the tanks and pumped to the primary settling tank. Not only does this sludge have a high water content, but it also contains oxygen and bacteria which improve the efficiency of the treatment process.

The gravity belt thickener is one way to reduce the amount of water in the biosolids before further treatment. The volume reduction is occurring from the loss of water. Thickening of the biosolids improves digester operation and reduces the cost of sludge digestion.

11. Primary Digest: Sludge removed throughout the process is pumped to digesters for processing. Anaerobic bacteria consume organic waste in the digesters. This process produces gases which can be used to fuel plant boilers and heat facilities.

Final Clarifiers are also used to settle out microorganisms (or "**bugs**") from the activated sludge process. Clarifiers are usually either round or rectangular in shape.

Once the wastewater leaves the final clarifier, it is typically disinfected to remove any bacteria. The solids are sent to a solids handling system, such as a solids thickener.

12. Dewatering Process: Vacuum filter or centrifuge systems remove water from the processed sludge to thicken it. The water removed in the process is pumped to the primary settling tank to reenter the treatment process.

13. Depending on **NPDES Permit**, the concentrated sludge, or bio-solid waste is taken away for incineration or conversion into fertilizer.



The end product of anaerobic digestion is a biologically stable substance that has nutrient and soil-enhancing properties, referred to as *Biosolids*. Biosolids are typically stored until the material can be land applied or disposed of in a landfill. Much of the biosolids produced are applied to farm land. Biosolids contain many of the same nutrients as commercial fertilizers, including valuable organic matter, nitrogen, phosphorus, calcium, magnesium, and micronutrients, such as zinc and iron.

While not a complete replacement for chemical fertilizers in terms of nutrient ratios, biosolids do some things that chemical fertilizers can't do. They are composed of organic matter that promotes necessary bacterial activity and improves the structure, texture, and water retention characteristics of the soil. These properties stimulate growth of vegetation, which helps reduce soil erosion and improve crop yields. Biosolids also provide trace metals and nutrients that commercial fertilizers do not have.

Trickling Filter

A trickling filter provides aerobic treatment of the wastewater. The wastewater is generally pumped from a compartment of the septic tank, dispersed over a media bed, and allowed to drain back into the tank. The wastewater is aerated as it flows over the media.

A Trickling Filter consists of a rotating arm that sprays wastewater over a filter medium. The filter medium can consist of rocks, plastic, or other material. The filter material is coarse, allowing air to flow through the media.

This process does not actually filter material out, however. Bacteria grow on the filter material. The bacteria then absorb and consume the waste as it trickles through the filter, improving the quality of the wastewater. The water is collected at the bottom of the filter for further treatment.

Aerobic Treatment Units

Aerobic treatment units use a biological process to transform dissolved and solid pollutants into gases, cell mass, and non-gradable material (EPA Manual). The treatment process occurs in a mixed state with a variety of microorganisms living together that can decompose a broad range of materials. The organisms live in an aerobic environment where free oxygen is available for the organism respiration. It is important to maintain an active population of microbes to carry out the breakdown of the solids.

Anaerobic Digestion

Anaerobic digestion is the biological degradation of organic matter in an oxygen free atmosphere. Anaerobic digestion converts the biosolids into carbon dioxide, methane, hydrogen sulfide, other gases, and water. What is left behind is a biologically stable residue, referred to as *biosolids*.

Typically, the biosolids are reused as a soil amendment. The biosolids are rich in nutrients and provide a good alternative to fertilizer.

Sand Filters

Sand filters are a biological and physical wastewater treatment component consisting of an under drained bed of sand to which pre-treated effluent is periodically applied.

A sand filter purifies the water through three main mechanisms: filtration, chemical sorption, and assimilation.

Wetland Systems

Wetland systems are used to remove biological materials, suspended solids, nutrients, and pathogens from the wastewater.

The constructed wetland wastewater treatment system consists of three components: septic tank, constructed wetland, and land application system. The wetland needs to have a sufficient cross sectional area to accept the water flow entering the wetland.





Covered basin used for odor control

WWT Acronyms and Abbreviations

A/O Pho-redox
A2/O 3 Stage Pho-redox
AT3 Aeration Tank 3
AOB Ammonia Oxidizing Bacteria
ASM Activated Sludge Model
BABE Bio-Augmentation Batch Enhanced
BAF Biological Aerated Filter
BAR Bio-Augmentation Regeneration/Reaeration
BCFS Biological Chemical Phosphorus and Nitrogen Removal
bDON Biodegradable Fraction of Dissolved Organic Nitrogen
BHRC Ballasted High Rate Clarification Processes
BNR Biological Nutrient Removal
BOD Biochemical Oxygen Demand
BOD5 Biochemical Oxygen Demand (5-day)
BPR Biological Phosphorus Removal
COD Chemical Oxygen Demand
CWA Clean Water Act
CWSRF Clean Water State Revolving Fund
CSO Combined Sewer Overflow
DAF Dissolved Air Flotation
DO Dissolved Oxygen
DON Dissolved Organic Nitrogen
E1 Estrone
E2 17 β -estradiol
EBPR Enhanced Biological Phosphorus Removal
EDC Endocrine Disrupting Chemicals
EDTA Ethylene Diamine Tetraacetic Acid
EE2 17 α -ethynylestradiol
EPA U.S. Environmental Protection Agency
FFS Fixed-film Systems
FWPCA Federal Water Pollution Control Act
FWS Free Water Surface
GAO Glycogen Accumulating Organism
HRSD Hampton Roads Sanitation District
HRT Hydraulic Retention Time
iDON Inert Dissolved Organic Nitrogen
ISF Intermittent Sand Filter
IWA International Water Association
JHB Johannesburg
MAUREEN Mainstream Autotrophic Recycle Enhanced N-removal
MBR Membrane Bioreactor
MBBR Moving-Bed Biofilm Reactor
MGD Million Gallons per Day
MLE Modified Ludzack Ettinger
MUCT Modified University of Capetown
N Nitrogen
NOAA National Oceanic and Atmospheric Administration
NOB Nitrite Oxidizing Bacteria
NPDES National Pollutant Discharge Elimination System
NTT Nitrogen Trading Tool
ORD EPA Office of Research and Development
ORP Oxidation Reduction Potential
OWASA Orange Water and Sewer Authority
OWM EPA Office of Wastewater Management
P Phosphorus

PAH Polycyclic Aromatic Hydrocarbons
PAO Phosphate Accumulating Organism
PHA Polyhydroxyalkanoates
PHB Poly-B-hydroxy-butyrate
PHV Poly-hydroxy valerate
POTW Publicly Owned Treatment Works
PPCPs Pharmaceuticals and Personal Care Products
RAS Return Activated Sludge
RBC Rotating Biological Contactor
rbCOD Readily Biodegradable Chemical Oxygen Demand
rDON Recalcitrant Dissolved Organic Nitrogen
RO Reverse Osmosis
RSF Recirculating Sand Filters
SAV Submerged Aquatic Vegetation
SBR Sequencing Batch Reactors
SHARON Single Reactor High-activity Ammonia Removal Over Nitrite
SND Simultaneous Nitrification-Denitrification
SRT Solids Retention Time
SSO Sanitary Sewer Overflow
STAC Chesapeake Bay Program Scientific and Technical Advisory Committee
SWIS Subsurface Wastewater Infiltration System
TDS Total Dissolved Solids
TKN Total Kjeldahl Nitrogen
TMDL Total Maximum Daily Loads
TN Total Nitrogen
TP Total Phosphorus
TSS Total Suspended Solids
TUDP Bio-P Model of the Delft University of Technology
UCT University of Capetown
USDA U.S. Department of Agriculture
USGS U.S. Geological Survey
VIP Virginia Initiative Plant
VFA Volatile Fatty Acids
VSS Volatile Suspended Solids
WAS Waste Activated Sludge
WEF Water Environment Federation
WERF Water Environment Research Foundation
WQS Water Quality Standard
WWTP Wastewater Treatment Plant

Need for Nitrogen and Phosphorus Removal at Wastewater Treatment Plants

The purpose of this section is to provide an overview of the major factors driving decisions to enhance nutrient removal at WWTPs. This section characterizes the industry based on U.S. Environmental Protection Agency (EPA) survey information. This section describes the negative impacts of nutrient enrichment, highlighting the history of water quality changes in key regions of the country. EPA and State initiatives to reduce nutrient pollution from wastewater treatment discharges are summarized in this training course. Lastly, we will highlight several barriers to enhancing nutrient removal at wastewater plants.

Status of Wastewater Treatment in the U.S.

The 1972 Amendments to the Federal Water Pollution Control Act (FWPCA)(Public Law 92-500), also known as the Clean Water Act (CWA), established the foundation for wastewater discharge control in the U.S. The CWA's primary objective is to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters." The CWA established a program to ensure clean water by requiring permits that limit the amount of pollutants discharged by all municipal and industrial dischargers into receiving waters. Discharges are regulated under the National Pollutant Discharge Elimination System (NPDES) permit program. As of 2004, there were 16,583 municipal wastewater utilities [also known as Publicly Owned Treatment Works (POTWs)] regulated under the CWA, serving approximately 75 percent of the Nation's population (U.S. Public Health Service and USEPA, 2008) with the remaining population served by septic or other onsite systems.

Wastewater treatment has generally been defined as containing one or more of the following four processes: (1) preliminary, (2) primary, (3) secondary, and (4) advanced - also known as tertiary treatment.

Preliminary treatment consists of grit removal, which removes dense inert particles and screening to remove rags and other large debris. Primary treatment involves gravity settling tanks to remove settleable solids, including settleable organic solids. The performance of primary settling tanks can be enhanced by adding chemicals to capture and flocculate smaller solid particles for removal and to precipitate phosphorus. Secondary treatment follows primary treatment in most plants and employs biological processes to remove colloidal and soluble organic matter. Effluent disinfection is usually included in the definition of secondary treatment.

EPA classifies advanced treatment as "a level of treatment that is more stringent than secondary or produces a significant reduction in conventional, non-conventional, or toxic pollutants present in the wastewater" (U.S. Public Health Service and USEPA, 2008). Other technical references subdivide advanced treatment, using the terms "secondary with nutrient removal" when nitrogen, phosphorus, or both are removed and "tertiary removal" to refer to additional reduction in solids by filters or microfilters (Tchobanoglous et al, 2003). Effluent filtration and nutrient removal are the most common advanced treatment processes.

The CWA requires that all municipal wastewater treatment plant discharges meet a minimum of secondary treatment. Based on data from the *2004 Clean Watersheds Needs Survey*, 16,543 municipal WWTPs (99.8 percent of plants in the country) meet the minimum secondary waste-water treatment requirements. Of those that provide at least secondary treatment, approximately 44 percent provide some kind of advanced treatment (U.S. Public Health Service and USEPA, 2008).

Nutrient Impairment of U.S. Waterways

The harmful effects of eutrophication due to excessive nitrogen and phosphorus concentrations in the aquatic environment have been well documented. Algae and phytoplankton growth can be accelerated by higher concentrations of nutrients as they can obtain sufficient carbon for growth from carbon dioxide. In addition to stimulating eutrophication, nitrogen in the form of ammonia can exert a direct demand on dissolved oxygen (DO) and can be toxic to aquatic life. Even if a treatment plant converts ammonia to nitrate by a biological nitrification process, the resultant nitrate can stimulate algae

and phytoplankton growth. Phosphorus also contributes to the growth of algae. Either nitrogen or phosphorus can be the limiting nutrient depending on the characteristics of the receiving water.

Nitrogen is typically limiting in estuarine and marine systems and phosphorus in fresh water systems. According to the 2007 report *Effects of Nutrient Enrichment in the Nation's Estuaries: A Decade of Change*, increased nutrient loadings promote a progression of symptoms beginning with excessive growth of phytoplankton and macroalgae to the point where grazers cannot control growth (Bricker et al., 2007). These blooms may be problematic, potentially lasting for months at a time and blocking sunlight to light-dependent submerged aquatic vegetation (SAV). In addition to increased growth, changes in naturally occurring ratios of nutrients may also affect which species dominate, potentially leading to nuisance/toxic algal blooms. These blooms may also lead to other more serious symptoms that affect biota, such as low DO and loss of SAV. Once water column nutrients have been depleted by phytoplankton and macroalgae and these blooms die, the bacteria decomposing the algae then consume oxygen, making it less available to surrounding aerobic aquatic life.

Consequently, fish and invertebrate kills may occur due to hypoxia and anoxia, conditions of low to no DO. Eutrophic conditions may also cause risks to human health, resulting from consumption of shellfish contaminated with algal toxins or direct exposure to waterborne toxins. Eutrophication can also create problems if the water is used as a source of drinking water. Chemicals used to disinfect drinking water will react with organic compounds in source water to form disinfection byproducts, which are potential carcinogens and are regulated by EPA.

Advanced eutrophic conditions can lead to “dead zones” with limited aquatic life, which describes the hypoxia condition that exists in the Northern Gulf of Mexico. A recent U.S. Geological Survey (USGS) report titled *Differences in Phosphorus and Nitrogen Delivery to the Gulf of Mexico from the Mississippi River Basin* documents the contribution of nitrogen and phosphorus from agricultural and non-agricultural sources in the Mississippi River basin (Alexander et al., 2008).

On June 16, 2008 the joint federal-state Mississippi River/Gulf of Mexico Watershed Nutrient Task Force released its *2008 Action Plan for Reducing, Mitigating, and Controlling Hypoxia in the Northern Gulf of Mexico and Improving Water Quality in the Mississippi River Basin*, which builds upon its 2001 plan by incorporating emerging issues, innovative approaches, and the latest science, including findings from EPA's Science Advisory Board.

Improvements include more accountability through an Annual Operating Plan, better tracking of progress, state and federal nutrient reduction strategies, and a plan to increase awareness of the problem and implementation of solutions (USEPA, 2008b). Nutrient pollution has also caused significant problems in the Chesapeake Bay. Elevated levels of both nitrogen and phosphorus are the main cause of poor water quality and loss of aquatic habitats in the Bay. Significant algae blooms on the water surface block the sun's rays from reaching underwater bay grasses. Without sunlight, bay grasses cannot grow and provide critical food and habitat for blue crabs, waterfowl, and juvenile fish. The Chesapeake Bay Program estimates that 22 percent of the phosphorus loading and 19 percent of the nitrogen loading in the Bay comes from municipal and industrial wastewater facilities (Chesapeake Bay Program, 2008).

The first national attention to nutrient contamination occurred in the Great Lakes. In the 1960s Lake Erie was declared “dead” when excessive nutrients in the Lake fostered excessive algae blooms that covered beaches and killed off native aquatic species due to oxygen depletion. At that time, phosphorus was the primary nutrient of concern due to the advent of phosphate detergents and inorganic fertilizers. With the enactment of the CWA and the Great Lakes Water Quality Agreement in 1972, a concerted effort was undertaken to reduce pollutant loadings, including phosphorus in the Lake.

Although the health of the Lake improved dramatically, in recent years, there has been renewed attention to the re-emergence of a “dead” zone in Lake Erie, again due to nutrient loadings. Recent studies by scientists and the National Oceanic and Atmospheric Administration (NOAA) have also hypothesized a relationship between excessive nutrients in the Lake and the presence of two aquatic invasive species – the zebra mussel and the quagga mussel (Vanderploeg et al., 2008). Development and population increases in the Long Island Sound Watershed have resulted in a significant increase in

nitrogen loading to the Sound. The increased nitrogen loads have stimulated plant growth, increased the amount of organic matter settling to the benthic zone, lowered DO levels, and changed habitats.

The primary concerns in the Sound include hypoxia, the loss of sea grass, and alterations in the food web. Management efforts are currently underway to reduce nitrogen pollution by more than half with a focus on upgrading WWTPs with new technologies and removing nitrogen by reducing polluted run-off through best management practices on farms and suburban areas (Long Island Sound Study, 2004). The above represent four examples of impaired large water bodies impacted by nutrient loadings. There are more than 80 additional estuaries and bays, and thousands of rivers, streams, and lakes that are also impacted by nutrients in the U.S. In fact, all but one state and two territories have CWA section 303(d) listed¹ water body impairments for nutrient pollution. Collectively, states have listed over 10,000 nutrient and nutrient-related impairments.

Climate change may also be a significant influence on the development of future eutrophic symptoms. According to the report *Effects of Nutrient Enrichment in the Nation's Estuaries: A Decade of Change*, the factors associated with climate change that are expected to have the greatest impacts on coastal eutrophication are:

- Increased temperatures
- Sea level rise
- Changes in precipitation and freshwater runoff

Increased temperatures will have several effects on coastal eutrophication. Most coastal species are adapted to a specific range of temperatures. Increases in water temperatures may lead to expanded ranges of undesirable species. Higher temperatures may also lead to increased algal growth and longer growing seasons, potentially increasing problems associated with excessive algal growth and nuisance/toxic blooms. Additionally, warmer waters hold less DO, therefore potentially exacerbating hypoxia. Temperature-related stratification of the water column may also worsen, having a further negative effect on DO levels.

Climate change models predict increased melting of polar icecaps and changes in precipitation patterns, leading to sea level rise and changes in water balance and circulation patterns in coastal systems. Sea level rise will gradually inundate coastal lands, causing increased erosion and sediment delivery to water bodies, and potentially flooding wetlands. The increased sediment load and subsequent turbidity increase may cause SAV loss. The positive feedback between increased erosion and algal growth (as erosion increases, sediment associated nutrients also increase, stimulating growth) may also increase turbidity. The loss of wetlands, which act as nutrient sinks, will further increase nutrient delivery to estuaries.

Another report titled *Aquatic Ecosystems and Global Climate Change – Potential Impacts on Inland Freshwater and Coastal Wetland Ecosystems in the United States* notes that climate change of the magnitude projected for the U.S. over the next 100 years will cause significant changes to temperature regimes and precipitation patterns across the U.S. (Poff et al., 2002). Such alterations in climate pose serious risks for inland freshwater ecosystems (lakes, streams, rivers, wetlands) and coastal wetlands, and may adversely affect numerous critical services provided to human populations.

These conclusions indicate climate change is a significant threat to the species composition and function of aquatic ecosystems in the U.S. However, critical uncertainties exist regarding the manner in which specific species and whole ecosystems will respond to climate change. These arise both from uncertainties about how regional climate will change and how complex ecological systems will respond.

Indeed, as climate change alters ecosystem productivity and species composition, many unforeseen ecological changes are expected that may threaten the goods and services that these systems provide to humans. Required by Section 303(d) of the CWA, the 303(d) list is a list of state's water bodies that do not meet or are not expected to meet applicable Water Quality Standards with technology-based controls alone.

Federal and State Initiatives to Reduce Nutrient Pollution

NPDES Permitting

Established by the FWPCA Amendment of 1972, EPA's NPDES permit program has been the primary mechanism for controlling pollution from point sources. Point sources are discrete conveyances such as pipes or man-made ditches. Individual homes that are connected to a municipal system, use a septic system, or do not have a surface discharge do not need an NPDES permit; however, POTWs and other facilities must obtain permits if they discharge directly to surface waters.

NPDES permits for wastewater discharges contain, among other information, effluent limits for "conventional" pollutants such as biochemical oxygen demand (BOD), total suspended solids (TSS), and pH as well as limits for specific toxicants including various organic and inorganic chemicals. Permits may also include effluent limits for "non-conventional" pollutants such as nitrogen and phosphorus. Effluent limits can be technology-based and/or water-quality based. EPA has established technology-based, secondary treatment effluent limits for BOD as 5-day biochemical oxygen demand (BOD₅), TSS, and pH.

Water-quality based effluent limits are set if the technology-based limits are not sufficient to maintain the water quality standards (WQS) of the receiving water. Federal and State regulations related to WQSs and Total Maximum Daily Loads (TMDLs) are expected to drive down NPDES effluent limits for nitrogen and phosphorus. WQS define the goals for a water body by designating its uses, setting criteria to protect those uses, and establishing provisions to protect water bodies from pollutants. Criteria can be narrative or numeric.

Regulatory agencies can adopt *nutrient criteria* to protect a water body against nutrient over-enrichment and eutrophication caused by nitrogen and phosphorus. In June 1998, EPA issued a *National Strategy for the Development of Regional Nutrient Criteria*. This was followed by publication of recommended nutrient criteria for most streams and lakes in 2001. In a January 9, 2001 *Federal Register* notice, EPA recommended that states and other regulatory agencies develop a nutrient criteria plan to outline their process for adopting such nutrient criteria (*Federal Register*, 2001).

As of May 2007, only a handful of States and Territories had adopted nutrient criteria for nitrogen and phosphorus (USEPA, 2007a), although many have made progress in criteria development. In a memo dated May 25, 2007, EPA encouraged all regulatory agencies to "...accelerate their efforts and give priority to adopting numeric nutrient standards or numeric translators for narrative standards for all waters in States and Territories that contribute nutrient loadings to our waterways" (USEPA, 2007b).

CWA Section 303(d) requires states to develop TMDLs for water bodies on the 303(d) list of impaired waters. A TMDL is a calculation of the maximum amount of a pollutant a water body can receive and still meet WQS. TMDLs serve as a tool for implementing WQS. The TMDL targets or endpoints represent a number where the applicable WQS and designated uses (e.g., such as public water supply, contact recreation, and the propagation and growth of aquatic life) are achieved and maintained in the water body of concern.

TMDLs identify the level of pollutant control necessary to meet WQS and support the designated uses of a water body. Once a TMDL is set, the total load is allocated among all existing sources. The allocation is divided into two portions - a load allocation representing natural and non-point sources and a waste load allocation representing NPDES permitted point source discharges. In many regions, water bodies have a poor ability to assimilate nutrients or water bodies are already impaired from past pollution and the water body cannot handle large loads of additional nutrients. In these cases, TMDLs may require nutrient permit levels to be even lower than what might be allowed otherwise by nutrient criteria.

Water Quality Trading

Water quality trading is a market-based approach to improve and preserve water quality. Trading can provide greater efficiency in achieving water quality goals by allowing one source to meet its regulatory obligations by using pollutant reductions created by another source that has lower pollution control costs. For example, under a water quality trading program, a POTW could comply with discharge requirements by paying distributed sources to reduce their discharges by a certain amount. The use of geographically-based trading ratios provides an economic incentive, encouraging action toward the most cost effective and environmentally beneficial projects.

EPA issued a Water Quality Trading Policy in 2003 to provide guidance to States and Tribes on how trading can occur under the CWA and its implementing regulations. The policy discusses CWA requirements that are relevant to water quality trading including: requirements to obtain permits, antibacksliding provisions, development of WQSs including an antidegradation policy, NPDES permit regulations, TMDLs and water quality management plans. EPA also developed a number of tools and guidance documents to assist states, permitted facilities, non-point sources, and stakeholders involved in the development of trading programs (www.epa.gov/owow/watershed/trading.htm). Recently, the U.S. Department of Agriculture (USDA) National Resources Conservation Service released a Nitrogen Trading Tool (NTT) prototype for calculating nitrogen credits based on the Nitrogen Loss and Environmental Assessment Package Model (Gross et al., 2008).

Water quality trading programs have been successfully implemented in several states and individual watersheds across the country. For example, nitrogen pollution from point sources into the Long Island Sound was reduced by nearly 25 percent using an innovative Nitrogen Credit Trading Program. In Connecticut, the program was implemented among 79 sewage treatment plants in the state. Through the Nitrogen Credit Exchange, established in 2002, the Connecticut program has a goal of reducing nitrogen discharges by 58.5 percent by 2014.

A recent American Society of Civil Engineers journal article points out, however, that regulatory frameworks for water quality trading programs have yet to be adopted by the majority of States. Barriers to adopting such programs include uncertainty in: (1) the mechanisms for determining appropriate credits and ratios between point sources and distributed sources; and (2) approaches to ensure that promised reductions actually occur (Landers, 2008).

Nutrient Constituents in Wastewater and Measurement Methods

This section provides an overview of the sources, forms, and measurement methods for nitrogen and phosphorus in wastewater.

Nitrogen

Nitrogen is an essential nutrient for plants and animals. Approximately 80 percent of the earth's atmosphere is composed of nitrogen and it is a key element of proteins and cells. The major contributors of nitrogen to wastewater are human activities such as food preparation, showering, and waste excretion. The per capita contribution of nitrogen in domestic wastewater is about 1/5th of that for BOD. Total nitrogen in domestic wastewater typically ranges from 20 to 70 mg/L for low to high strength wastewater (Tchobanoglous et al., 2003). Factors affecting concentration include the extent of infiltration and the presence of industries. Influent concentration varies during the day and can vary significantly during rainfall events, as a result of inflow and infiltration to the collection system.

The most common forms of nitrogen in wastewater are:

- Ammonia (NH_3)
- Ammonium ion (NH_4^+)
- Nitrite (NO_2^-)
- Nitrate (NO_3^-)
- Organic nitrogen

Nitrogen in domestic wastewater consists of approximately 60 to 70 percent ammonia-nitrogen and 30 to 40 percent organic nitrogen (Tchobanoglous et al., 2003; Crites and Tchobanoglous, 1998). Most of the ammonia-nitrogen is derived from urea, which breaks down rapidly to ammonia in wastewater influent. EPA approved methods for measuring ammonia, nitrate, and nitrite concentration use colorimetric techniques. Organic nitrogen is approximated using the standard method for Total Kjeldahl Nitrogen (TKN) (APHA, AWWA, and WEF, 1998).

The TKN method has three major steps:

- (1) digestion to convert organic nitrogen to ammonium sulfate;
- (2) conversion of ammonium sulfate into condensed ammonia gas through addition of a strong base and boiling; and
- (3) measurement using colorimetric or titration methods. Because the measured concentration includes ammonia, the ammonia-nitrogen concentration is subtracted from the TKN to determine organic nitrogen.

Nitrogen components in wastewater are typically reported on an "as nitrogen" basis so that the total nitrogen concentration can be accounted for as the influent nitrogen components are converted to other nitrogen compounds in wastewater treatment.

WWTPs designed for nitrification and denitrification can remove 80 to 95 percent of inorganic nitrogen, but the removal of organic nitrogen is typically much less efficient (Pehlivanoglu-Mantas and Sedlak, 2006). Domestic wastewater organic nitrogen may be present in particulate, colloidal or dissolved forms and consist of proteins, amino acids, aliphatic N compounds, refractory natural compounds in drinking water (e.g. humic substances), or synthetic compounds (e.g. ethylene Diamine tetraacetic acid (EDTA)). Organic nitrogen may be released in secondary treatment by microorganisms either through metabolism or upon death and lysis. Some nitrogen may be contained in recondensation products. Hydrolysis of particulate and colloidal material by microorganisms releases some organic nitrogen as dissolved, biodegradable compounds. Amino acids are readily degraded during secondary biological treatment, with 90 to 98 percent removal in activated sludge systems and 76 to 96 percent removal in trickling filters. However, other forms of organic nitrogen may be more persistent in wastewater treatment processes.

The importance of organic nitrogen has increased as effluent limits on nitrogen have become more stringent. With more impaired waterways from nutrient loads, effluent limits for total nitrogen (TN) concentrations of 3.0 mg/L or less are becoming more common. The dissolved organic nitrogen (DON) concentration in the effluent from biological nutrient removal treatment facilities was found to range from

0.50 to 1.50 mg/L in 80 percent of 188 plants reported by Pagilla (STAC-WERF, 2007) and values as high as 2.5 mg/L were observed. Thus, for systems without effluent filtration or membrane bioreactors (MBRs) that are trying to meet a TN treatment goal of 3.0 mg/L, the effluent DON contribution can easily be 20 to 50 percent of the total effluent nitrogen concentration, compared to only about 10 percent for conventional treatment (Pehlivanoglu-Mantas and Sedlak, 2004).

The chemical composition of DON in wastewater effluents is not completely understood. Sedlak (2007) has suggested that only about 20 percent of the DON has been identified as free and combined amino acids, EDTA, and other trace nitrogen compounds. About 45 percent may be unidentified low molecular weight compounds and the other 35 percent as unidentified high molecular weight compounds containing humic acids and amides. Similar results were found by Khan (2007). Early work by Parkin and McCarty (1981) suggested that 40 to 60 percent of effluent DON is non-bioavailable. The non-bioavailable portion is also referred to as recalcitrant DON (rDON).

Phosphorus

Total phosphorus (TP) in domestic wastewater typically ranges between 4 and 8 mg/L but can be higher depending on industrial sources, water conservation, or whether a detergent ban is in place. Sources of phosphorus are varied. Some phosphorus is present in all biological material, as it is an essential nutrient and part of a cell's energy cycle. Phosphorus is used in fertilizers, detergents, and cleaning agents and is present in human and animal waste.

Phosphorus in wastewater is in one of three forms:

- Phosphate (also called Orthophosphate)
- Polyphosphate, or
- Organically bound phosphorus.

The orthophosphate fraction is soluble and can be in one of several forms (e.g., phosphoric acid, phosphate ion) depending on the solution pH. Polyphosphates are high-energy, condensed phosphates such as pyrophosphate and trimetaphosphate. They are also soluble but will not be precipitated out of wastewater by metal salts or lime. They can be converted to phosphate through hydrolysis, which is very slow, or by biological activity. Organically bound phosphorus can either be in the form of soluble colloids or particulate. It can also be divided into biodegradable and non-biodegradable fractions. Particulate organically bound phosphorus is generally precipitated out and removed with the sludge. Soluble organically bound biodegradable phosphorus can be hydrolyzed into orthophosphate during the treatment process.

Soluble organically bound non-biodegradable phosphorus will pass through a wastewater treatment plant. A typical wastewater contains 3 to 4 mg/L phosphorus as phosphate, 2 to 3 mg/L as polyphosphate, and 1 mg/L as organically bound phosphorus (WEF and ASCE, 2006).

Phosphorus content in wastewater can be measured as

- Orthophosphate
- Dissolved orthophosphate
- Total phosphorus
- Total dissolved phosphorus (i.e., all forms except particulate organic phosphorus)

EPA approved laboratory methods rely on colorimetric analysis. Colorimetric analysis measures orthophosphate only, so a digestion step is needed to convert polyphosphate and organic phosphorus to orthophosphate to measure TP. The persulfate method is reported to be the most common and easiest method (WEF and ASCE, 2006). To determine dissolved phosphorus (either total dissolved phosphorus or total dissolved orthophosphate), the sample is first filtered through a 0.45 micron filter. USEPA approved colorimetric methods are routinely used to measure phosphorus levels as low as 0.01 mg/L. On-line analyzers that use the colorimetric method are available from vendors (e.g., the Hach Phosphax™ SC phosphate analyzer). Ion chromatography is a second common technique used to measure orthophosphate in waste-water. As with colorimetric methods, digestion is required for TP measurement, with persulfate digestion recommended (WEF and ASCE, 2006).

Phosphorus Removal by Chemical Addition

The purpose of this section is to describe techniques for phosphorus removal by chemical addition. It summarizes issues associated with chemical feed location, mixing, and sludge production. An overview of advanced solids separation processes is also provided.

Principles

Chemical precipitation for phosphorus removal is a reliable, time-tested, wastewater treatment method that has not drastically changed over the years. To achieve removal, various coagulant aids are added to wastewater where they react with soluble phosphates to form precipitates. The precipitates are removed using a solids separation process, most commonly settling (clarification). Chemical precipitation is typically accomplished using either lime or a metal salt such as aluminum sulfate (alum) or ferric chloride. The addition of polymers and other substances can further enhance floc formation and solids settling. Operators can use existing secondary clarifiers or retrofit primary clarifiers for their specific purposes.

Aluminum and Iron Salts

Alum and ferric or ferrous salts are commonly used as coagulant and settling aids in both the water and wastewater industry. They are less corrosive, create less sludge, and are more popular with operators compared to lime. Alum is available in liquid or dry form, can be stored on site in steel or mild concrete, and has a near unlimited shelf life. Ferric chloride is similar although care is needed during handling because of corrosivity. If an industrial source is available such as waste pickle liquor, ferrous chloride or ferrous sulfate have been used for phosphorus removal. Ferrous forms should be added directly to aerobic reactors rather than to anaerobic reactors such as primary settling basins because the ferrous iron needs to oxidize to ferric iron for best results.

The molar ratio of aluminum to phosphorus required for phosphorus removal ranges from about 1.38:1 for 75 percent removal, 1.72:1 for 85 percent removal, and 2.3:1 for 95 percent removal.

For iron compounds, a ratio of about 1:1 is required, with a supplemental amount of iron (10 mg/L) added to satisfy the formation of hydroxide (WEF and ASCE, 1998). For additional removal of phosphorus with aluminum and iron salts, a ratio of between 2 and 6 parts metal salt to 1 part phosphorus may be required for adequate phosphorus removal.

To supplement stoichiometry calculations, designers should consider jar tests and, in some cases, full-scale pilot tests to gauge the effects on the required dose of competing reactions; the influence of pH and alkalinity, adsorption, and co-precipitation reactions; and the interaction with polymers that are added to increase coagulation and flocculation (WEF and ASCE, 1998; Bott et al. 2007).

Aluminum or ferric iron salts can be added to the primary clarifier, secondary clarifier, tertiary clarifier, or directly into the activated sludge aeration tank. Multiple additions can increase phosphorus removal efficiency. Ferrous salts can only be added to the aeration basin since it needs to be oxidized to ferric to precipitate the phosphorus.

The solubility of aluminum and iron salts is a function of pH. The optimum solubility for alum was previously reported to occur at a pH range of 5.5 to 6.5, significantly lower than most influent wastewater. Recent studies (Szabo et al., 2008) showed that the range for both iron and alum is between 3.5 and 7.5 with the highest efficiency between pH 5.5 and 7.

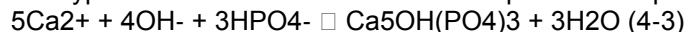
Chemicals such as lime compounds, caustic soda, and soda ash can be used to raise the pH of the waste stream prior to biological treatment processes or discharge. It is important to understand that alkalinity is consumed during the precipitation reactions, and precipitation will be incomplete if insufficient alkalinity is present.

Lime

Although lime had lost favor due to issues associated with chemical handling, sludge production, and re-carbonation, it has recently been considered more often because of its ability to reduce phosphorus to very low levels when combined with effluent filtration and the microbial control properties associated with its high pH. When lime is added to wastewater, it first reacts with the bicarbonate alkalinity to form calcium carbonate (CaCO_3). As the pH increases to more than 10, excess calcium ions will react with phosphate to precipitate hydroxylapatite [$\text{Ca}_5(\text{OH})(\text{PO}_4)_3$].

Because it reacts first with alkalinity, the lime dose is essentially independent of the influent phosphorus concentration. Tchobanoglous et al. (2003) estimates the lime dose to typically be 1.4 to 1.6 times the total alkalinity expressed as CaCO_3 .

The typical reaction between calcium compounds and phosphorus is represented below:



The molar ratio required for phosphorus precipitation with lime is approximately 5:3, but can vary from between 1.3 to 2, depending on the composition of the wastewater. As with iron and aluminum salts, jar tests can be used to determine correct doses for a specific wastewater stream (WEF, 1998).

Lime addition can raise the pH to greater than 11. Because activated sludge processes require pH levels below 9, lime cannot be added directly to biological treatment processes or it will cause process upsets. Lime can be added to primary sedimentation tanks and removed with the primary sludge or it can be added as a tertiary treatment process after biological treatment. When added to primary tanks, it will also result in the removal of colloidal material through coagulation and settling, with a concomitant removal of TSS up to 80 percent and chemical oxygen demand (COD) up to 60 percent.

In either case, pH adjustment is needed and typically accomplished by adding CO_2 or a liquid acid such as sulfuric acid, nitric acid, or hypochlorite (Tchobanoglous et al., 2003; USEPA, 1999a).

Hortskotte et al. (1974) showed that when the primary effluent is discharged directly to a nitrifying activated sludge plant, the hydrogen ions produced may neutralize the high pH. However, when denitrification is practiced and the operator wishes to make use of the soluble COD in the primary effluent, the effluent must be neutralized before discharging it to the anoxic zone.

Lime requires special handling and operations practices that further set it apart from chemical precipitation by metal salts. Although the formation of carbonate scaling on equipment and pipes is a drawback of lime treatment, lime slaking, where quicklime (CaO) is reacted with water to form calcium hydroxide ($\text{Ca}(\text{OH})_2$), is the biggest operational disadvantage.

Location of Chemical Feed and Mixing

Lime or metal salts can be added at several locations throughout the treatment plant to remove phosphorus. “Pre-precipitation” is when chemicals are added to raw water to precipitate phosphorus in the primary sedimentation basins. “Co-precipitation” involves adding chemicals to form precipitates that can be removed with biological sludge. “Post-precipitation” is when chemicals are added after secondary sedimentation and precipitants are removed in a tertiary process such as sedimentation or filtration (Tchobanoglous et al., 2003). Because it requires a high pH to achieve a low phosphorus concentration, lime cannot be added directly to biological reactors or to the secondary clarifiers.

Multipoint additions of iron or aluminum salts have been very effective and can typically remove more phosphorus than single-point applications. There are several advantages to post-precipitating phosphorous using a tertiary treatment technique (after biological processes in a separate reactor):

- Microorganisms rely on phosphorus as a food source. If too much phosphorus is removed prior to biological treatment, biological processes may suffer. For activated sludge, the minimum ratio of phosphorus to BOD₅ for a rapidly growing (low solids retention time (SRT)) system is typically about 1:100 (WEF and ASCE, 1998).
- Competing chemicals in the primary sedimentation basins can increase the required dose.
- Phosphorus enters the treatment plant as soluble orthophosphate, soluble polyphosphates, and organically bound phosphorus. Most of the polyphosphates and much of the organically bound phosphorus are converted to more simple orthophosphates during biological treatment. If the influent contains significant polyphosphates and/or organically bound phosphorus, locating chemical treatment after biological processes would be more efficient and achieve lower effluent levels.
- The removal of carbonate alkalinity and phosphorus by lime prior to biological treatment can have a negative impact on nitrification processes (WEF and ASCE, 1998). Also, removing phosphorus to very low concentrations upstream of denitrification filters can negatively affect the denitrification process. Previous studies showed that the hydroxide alkalinity can be balanced by the hydrogen ions produced during nitrification.
- Sludge recalcification can be used to achieve high removal efficiencies using lime in tertiary treatment. One potential advantage to adding chemicals during primary treatment instead of tertiary treatment is reduced capital costs and space requirements as a result of removing additional BOD and TSS and reducing the load to downstream processes, thereby reducing the size of the subsequent activated sludge basins and the amount of oxygen transfer needed.

Chemicals should be well mixed with the wastewater to ensure reaction with soluble phosphates and formation of precipitates. Chemicals may either be mixed in separate tanks or can be added at a point in the process where mixing already occurs. Bench-scale and pilot scale tests are often used to determine the correct mixing rate for a given composition of wastewater and chemicals used, including polymer (USEPA, 1999a).

Advanced Solids Separation Processes

The effectiveness of phosphorus removal by chemical addition is highly dependent on the solids separation process following chemical precipitation. Direct addition of metal salts to activated sludge processes followed by conventional clarification can typically remove TP to effluent levels between 0.5 and 1.0 mg/L (Bott et al., 2007). Tertiary processes (post-secondary treatment) can be used to remove phosphorus to very low (< 0.1 mg/L) concentrations. For example, Reardon (2005) reports that four WWTP with tertiary clarifiers achieved TP levels of between 0.032 and 0.62 mg/L. Two common tertiary processes are clarification and effluent filtration. These approaches can be used separately or in combination. Section 7 presents a detailed discussion of effluent filtration. Advances in tertiary clarification processes are discussed below.

The types of clarifiers used for tertiary processes include conventional, one or two-stage lime, solids-contact, high-rate, and ballasted high-rate (BHRC). Several patented BHRC using different types of ballast such as recycled sludge, microsand, and magnetic ballast (USEPA, 2008a) have been developed in recent years. The advantages of high-rate clarification are that the clarifiers have a smaller footprint and are able to treat larger quantities of wastewater in a shorter period of time. In addition, as an add-on during wet weather, they can help prevent sanitary sewer overflows (SSOs) and combined sewer overflows (CSOs).

The following patented processes are examples of high rate clarification including performance estimates:

- DensaDeg® uses a coagulant in a rapid mix basin to destabilize suspended solids. The water flows into a second tank where polymer (for aiding flocculation) and sludge are added. The sludge acts as the “seed” for formation of high density floc. This floc is removed in settling tubes (USEPA, 2008). The main advantages of this process are a smaller footprint and denser sludge which is easier to dewater. Pilot testing for City of Fort Worth, Texas found a phosphorus removal rate of 88-95% for DensaDeg® (USEPA, 2003).

- Actiflo® uses a coagulant in a rapid mix basin to destabilize suspended solids. The water flows to a second tank where polymer (for aiding flocculation) and microsand are added. Microsand provides a large surface onto which suspended solids attach, creating a dense floc that settles out quickly. Clarification is assisted by lamella settling. Product pilot testing in Fort Worth, Texas showed a phosphorus removal efficiency of 92-96% for Actiflo® (USEPA, 2003).

- The CoMag process uses the addition of magnetic ballast with metal salts to promote floc formation. Settling is followed by high gradient magnetic separation for effluent polishing and recovery of the magnetic ballast (USEPA, 2008a). CoMag is currently in operation at a 4.0 million gallons per day (MGD) wastewater treatment plant in Concord, Massachusetts. The vendor has guaranteed an effluent phosphorus concentration not to exceed 0.05 mg/L (EPA Region 10, 2007).

Other Design and Operational Issues

Phosphorus removal by chemical addition is limited to the soluble phosphates in the waste stream. Organically bound phosphorus and polyphosphates will not be removed by chemical treatment unless they are coagulated with the chemicals and removed in the sludge. Chemicals can be added after biological treatment to capitalize on the conversion of polyphosphates and organically bound phosphorus to phosphates by microorganisms in activated sludge.

The success of phosphorus removal by chemical addition depends on proper instrumentation and control. Dosage control typically takes the form of manual operation (for small systems), adjustments based on automatic flow measurements, or the more advanced on-line analyzers with computer-assisted dosage control. Chemical properties of any water used for making solutions should be considered – tap water high in suspended solids could cause sludge to form when mixed with coagulants (WEF and ASCE, 1998) and could lead to clogging of chemical feed lines. Smith et al. (2008) found that factors such as pH, complexation, mixing, and the coagulant used can limit the removal of phosphorus, especially in the range of <0.1 mg/L.

Impacts on Sludge Handling and Production

Sludge handling and production is generally considered to be one of the main downsides of chemical addition. Chemical precipitation methods always produce additional solids due to generation of metal- or calcium- phosphate precipitates and additional suspended solids (WEF and ASCE, 1998). Chemically treated sludge has a higher inorganic content compared to primary and activated sludge and will increase the required size of aerobic and anaerobic digesters. Additional sludge production can be estimated using reaction equations. The use of metal salts can result in increased inorganic salts (salinity) in the sludge and in the effluent.

Salinity can create problems when biosolids are land applied or when the effluent is returned to existing water supply reservoirs. Biological phosphorus removal was developed in South Africa due to the high rate of indirect recycling of wastewater effluent which led to excessive total dissolved solids (TDS) during dry periods. High total salts can reduce germination rates for crops and negatively affect the soil structure.

Lime traditionally produces a higher sludge volume compared to metal salts because of its reaction with natural alkalinity. An advantage of lime sludge is that some stabilization can occur due to the high pH levels required. One disadvantage is that lime can cause scaling in mechanical thickening and dewatering systems. There are also differences in the amount and characteristics of sludge generated by alum versus ferric salts. Although alum tends to produce less sludge than do ferric salts, alum sludge can be more difficult to concentrate and dewater compared to ferric sludge.

Biological Nitrogen Removal

This section provides an overview of the principles behind biological nitrogen removal and describes the common design configurations in use today. It identifies key operational and design issues (including impacts on sludge handling and production), provides general guidelines on process selection, and summarizes ongoing research efforts in this area. Process configurations that are designed to remove both nitrogen and phosphorus are described latter.

Principles

In wastewater treatment, nitrogen removal occurs in two sequential processes: nitrification and denitrification. An overview of each process is provided below.

Nitrification

Nitrification is an aerobic process in which autotrophic bacteria oxidize ammonia or nitrite for energy production. Nitrification is normally a two-step aerobic biological process for the oxidation of ammonia to nitrate. Ammonia-nitrogen ($\text{NH}_3\text{-N}$) is first converted to nitrite (NO_2^-) by ammonia oxidizing bacteria (AOB). The nitrite produced is then converted to nitrate (NO_3^-) by nitrite oxidizing bacteria (NOB). Both reactions usually occur in the same process unit at a wastewater treatment plant (e.g. activated sludge mixed liquor or fixed film biofilm).

The group of AOB most associated with nitrification is the *Nitrosomonas* genus, although other AOB such as *Nitrosococcus* and *Nitrosospira* can contribute to the process. *Nitrobacter* are the NOB most associated with the second step, although other bacteria including *Nitrospina*, *Nitrococcus*, and *Nitrospira* have been found to also oxidize nitrite (Tchobanoglous et al., 2003; USEPA, 2007c).

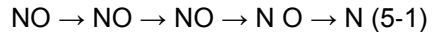
AOB and NOB are classified as autotrophic bacteria because they derive energy from the oxidation of reduced inorganic compounds (in this case, nitrogenous compounds) and use inorganic carbon (CO_2) as a food source. Nitrifying bacteria require a significant amount of oxygen to complete the reactions, produce a small amount of biomass, and cause destruction of alkalinity through the consumption of carbon dioxide and production of hydrogen ions. For each gram (g) of $\text{NH}_3\text{-N}$ converted to nitrate, 4.57 g of oxygen are used, 0.16 g of new cells are formed, 7.14 g of alkalinity are removed, and 0.08 g of inorganic carbon are utilized in formation of new cells (Tchobanoglous et al., 2003).

Nitrifying bacteria grow slower and have much lower yields as a function of substrate consumed, compared to the heterotrophic bacteria in biological treatment processes. The maximum specific growth rate of the nitrifying bacteria is 10 to 20 times less than the maximum specific growth rate of heterotrophic bacteria responsible for oxidation of carbonaceous organic compounds in waste-water treatment.

Thus, the nitrification process needs a significantly higher SRT to work compared to conventional activated sludge processes. The SRT needed for nitrification in an activated sludge process is a function of the maximum specific growth rate (which is related to temperature), the reactor dissolved oxygen concentration, and pH. Nitrification rates decline as the DO concentration decreases below 3.0 mg/L and the pH decreases below 7.0 mg/L. With sufficient DO and adequate pH, typical nitrification design SRTs range from 10 to 20 days at 10°C and 4 to 7 days at 20°C (Randall et al., 1992).

Denitrification

In municipal and industrial wastewater treatment processes, denitrification is the biological reduction of nitrate or nitrite to nitrogen gas (N₂) as indicated by equation below.



It is accomplished by a variety of common heterotrophic microorganisms that are normally present in aerobic biological processes. Most are facultative aerobic bacteria with the ability to use elemental oxygen, nitrate, or nitrite as their terminal electron acceptors for the oxidation of organic material.

Heterotrophic bacteria capable of denitrification include the following genera: *Achromobacter*, *Acinetobacter*, *Agrobacterium*, *Alcaligenes*, *Arthrobacter*, *Bacillus*, *Chromobacterium*, *Corynebacterium*, *Flavobacterium*, *Hypomicrobium*, *Moraxella*, *Nesseria*, *Paracoccus*, *Propionibacteria*, *Pseudomonas*, *Rhizobium*, *Rhodopseudomonas*, *Spirillum* and *Vibrio* (Tchobanoglous et al., 2003).

Recent research has shown that nitrite reduction is accomplished by a much more specialized group of heterotrophic bacteria than those performing the conversion of nitrate to nitrite (Katehis, 2007).

Denitrification by heterotrophic nitrifying bacteria and by autotrophic bacteria has also been observed. An example of a heterotrophic nitrifying bacteria that can denitrify is *Parococcus pantotropha*, which obtains energy by nitrate or nitrite reduction while oxidizing ammonia under aerobic conditions. A readily available carbon source, such as acetate, is needed (Robertson and Kuenen, 1990). The conditions required for this form of denitrification are not practical in biological wastewater treatment.

An autotrophic denitrifying bacteria of practical significance in wastewater treatment is that in the Anammox process used to remove nitrogen in return streams from anaerobic digestion sludge dewatering filtrate or centrate. These bacteria have been identified as a member of bacteria in the order *Planctomycetales* (Strous et al, 1999). Under anaerobic conditions, ammonia is oxidized with the reduction of nitrite with the final product as nitrogen gas. The reaction is best accomplished at temperatures above 25°C and they are slow growing organisms.

Facultative denitrifying bacteria will preferentially use oxygen instead of nitrate. In the absence of oxygen, however, they will carry out nitrite and/or nitrate reduction. Microbiologists generally use the term anaerobic to describe biological reactions in the absence of oxygen. To distinguish anaerobic conditions for which the biological activity occurs mainly with nitrate or nitrite as the electron acceptor, the term “anoxic” has been applied.

Although oxygen is known to inhibit denitrification, denitrification has been observed in activated sludge and fixed film systems in which the bulk liquid DO concentration is positive. This is due to the establishment of an anoxic zone within the floc or biofilm depth. Hence, a single system can carry out simultaneous nitrification and denitrification. The DO concentration that is possible for simultaneous nitrification and denitrification depends on a number of factors including the mixed liquor concentration, temperature, and substrate loading. The DO concentration above which denitrification is inhibited may vary from 0.10 to 0.50 mg/L (WEF and ASCE, 2006; Tchobanoglous et al., 2003; Barker and Dold, 1997).

The organic carbon source for denitrifying bacteria can be in the form of:

- Soluble degradable organics in the influent wastewater
- Soluble organic material produced by hydrolysis of influent particulate material
- Organic matter released during biomass endogenous decay

A general rule of thumb is that 4 g of wastewater influent BOD is needed per g of NO₃-N to be removed through biological treatment (Tchobanoglous et al., 2003). When denitrification occurs after secondary treatment, there is little BOD remaining so a supplemental carbon source is often needed. The most common exogenous carbon source in use is methanol; however, due to issues regarding its safety, cost, and availability, some wastewater systems are using alternative carbon sources such as acetic acid, ethanol, sugar, glycerol, and proprietary solutions depending on the needs of their particular facility (deBarbadillo et al., 2008). See Section 5.3 for additional discussion on supplemental carbon sources.

Biological denitrification reactions produce alkalinity and heterotrophic biomass. Based on the stoichiometry of the reactions, denitrification will produce a 3.57 mg/L of alkalinity as CaCO₃ for each mg/L of NO₃⁻-N consumed. Heterotrophic biomass produced can be estimated as 0.4 g volatile suspended solids (VSS) produced for every gram of COD consumed. Growth kinetics for denitrifiers are dependent on a number of factors including carbon substrate type and concentration, DO concentration, alkalinity, pH, and temperature, with carbon source being the most important.

Current Configurations

Biological nitrogen removal can be accomplished by a variety of treatment configurations using suspended growth, attached growth, or combined systems. In the past, some WWTPs were required to only remove ammonia-nitrogen in wastewater to reduce toxicity to aquatic organisms with no limits on nitrate or total nitrogen. However, most treatment plants are now required to remove nitrogen because both ammonia-nitrogen and nitrate-nitrogen can stimulate algae and phytoplankton growth and lead to eutrophication of U.S. waterways. For biological nitrogen removal, it is essential that nitrification occur first followed by denitrification.

Biological Nitrogen Removal Process Configurations

Biological nitrogen removal systems achieve nitrification and denitrification along with BOD reduction in bioreactors followed by secondary clarification. Processes can be either suspended growth or hybrid systems that use a combination of attached growth (biofilms) and suspended growth technologies. Configurations within each of these classifications are discussed below. Note that biological processes that removal both nitrogen and phosphorus are discussed later in this manual.

Suspended Growth Systems Modified Ludzck Ettinger (MLE) process

The most common nitrogen removal process used at WWTPs is the Modified Ludzck Ettinger (MLE) process, which is considered a pre-denitrification, single sludge system. The process includes an initial anoxic zone, followed by an aerobic zone. In the anoxic zone, nitrate produced in the aerobic zone is reduced to nitrogen gas. This process uses some of the BOD in the incoming waste. Nitrification occurs in the aerobic zone along with the removal of most of the remaining BOD. At the end of the aerobic zone, pumps recycle the nitrate-rich mixed liquor to the anoxic zone for denitrification.

Total nitrogen removal for the MLE process is typically 80 percent, and the process achieves total effluent nitrogen concentrations ranging from approximately 5 to 8 mg/L with internal nitrate recycle ratios of 2 to 4 based on the influent flowrate (2-4Q).

Four-Stage Bardenpho Process

The four-stage Bardenpho process builds on the MLE process, with the first two stages being identical to the MLE system (anoxic zone followed by an aeration zone with a nitrate-rich recycle from the aeration to the anoxic zone). The third stage is a secondary anoxic zone to provide denitrification to the portion of the flow that is not recycled to the primary anoxic zone. Methanol or another carbon source can be added to this zone to enhance denitrification. The fourth and final zone is a re-aeration zone that serves to strip any nitrogen gas and increase the DO concentration before clarification. Some configurations have used an oxidation ditch instead of the first two stages. This process can achieve effluent TN levels of 3 to 5 mg/L.

Sequencing Batch Reactors

Sequencing batch reactors (SBRs) are fill and draw batch systems in which all treatment steps are performed in sequence for a discrete volume of water in a single or set of reactor basins.

SBRs use four basic phases for most systems:

Fill: water is added to the basin and is aerated and mixed

React: Biological processes are performed

Settle: All aeration and mixing is turned off and the biomass is allowed to settle

Decant: Clarified effluent is removed and biomass is wasted as necessary

The SBR control system allows it to mimic most other suspended growth processes such as the MLE or Four-Stage Bardenpho system. It typically completes 4 to 6 cycles per day per tank for domestic wastewater. If properly designed and operated, SBRs can achieve about 90 percent removal of nitrogen (WEF and ASCE, 2006).

Oxidation Ditches

Oxidation ditches are looped channels that provide continuous circulation of wastewater and biomass. A number of operating methods and designs have been developed to achieve nitrogen removal, all of which work by cycling the flow within the ditch between aerobic and anoxic conditions. DO can be added to the aerated zone using horizontal brush aerators, diffused aerators with submersible mixers, or vertical shaft aerators (WEF and ASCE, 2006). Patented designs include the NITROX process, Carrousel, and BioDenitro (WERF, 2000a). Many oxidation ditch configurations can achieve simultaneous nitrogen and phosphorus removal.

Step Feed

The step feed biological nitrogen removal process splits the influent flow and directs a portion of it to each of several anoxic zones, with the highest proportion of influent flow going to the first zone and steadily decreasing until the last anoxic zone prior to clarification. The biomass in the later stages are not just treating influent flow but are also used to reduce nitrate from the upstream zones. The step feed system provides flexibility for systems to handle wet-weather events. It can also be compatible with existing conventional “plug flow” activated sludge processes and it does not require the installation of recycle pumps and piping. Disadvantages include the need to control the DO concentration of aeration zones preceding the downstream anoxic zones and the need to control the flow splitting to the step feed points.

Attached Growth and Hybrid Systems Integrated Fixed-Film Activated Sludge (IFAS)

Integrated fixed-film activated sludge (IFAS) is any suspended growth system (e.g., MLE, Four-Stage Bardenpho) that incorporates an attached growth media within the suspended growth reactor in order to increase the amount of biomass in the basin. IFAS systems have higher treatment rates than suspended growth systems and generate sludge with better settling characteristics. Many types of fixed and floating media are available, including:

- **Rope:** also called looped-cord or strand media. Consists of a polyvinyl chloride-based material woven into rope with loops along the length to provide surface area for the biomass (WERF, 2000b). Proprietary designs include Ringlace, Bioweb, and Biomatrix (USEPA, 2008a).
- **Moving Bed with Sponge:** proprietary products include Captor and Linpor (USEPA, 2008a).
- **Plastic Media:** several types of free-floating plastic media are available from Kaldness. Other media types include fabric mesh (e.g., AccuWeb) and textile material (Cleartec).

Moving-Bed Biofilm Reactor (MBBR)

The moving-bed biofilm reactor (MBBR) is similar to the IFAS system in that it uses plastic media with a large surface area to increase biomass within the biological reactor. The MBBR media is submerged in a completely mixed anoxic or aerobic zone. The plastic media are typically shaped like small cylinders to maximize surface area for biomass growth. The difference between MBBR and IFAS is that MBBR does not incorporate return sludge (WERF, 2000b).

Membrane Bioreactor (MBR)

MBRs are commonly designed for nitrogen removal, using membranes for liquid-solids separation following the anoxic and aerobic zones instead of conventional clarification. Membranes can be submersed in the biological reactor or located in a separate stage or compartment.

Separate Stage Nitrification and Denitrification Systems

Suspended Growth Nitrification

Single-sludge systems for BOD removal and nitrification require that the biomass inventory be retained long enough to establish a stable population of nitrifiers and that the HRT be such that the biomass can react with the ammonia-nitrogen entering the system. The overall approach for designing such systems is to determine the target SRT for the system based on influent characteristics (i.e., BOD, ammonia-nitrogen, organic nitrogen), environmental conditions such as temperature and flow characteristics (i.e., average daily, maximum monthly, diurnal peak).

Most activated sludge treatment plants will readily nitrify if they have sufficient aerobic SRT and can deliver sufficient oxygen maintaining 2 mg/L DO or greater. For plants having difficulty in nitrifying due to insufficient tank volume, there are some emerging technologies which can improve the process.

One of these is bioaugmentation. Bioaugmentation is accomplished by seeding the activated sludge process with an external source of nitrifying bacteria (also known as external bioaugmentation) or making process improvements to increase the activity of or enrich the nitrifier population (also known as *in situ* bioaugmentation).

External bioaugmentation uses either commercial sources of nitrifiers or sidestream processes to grow nitrifiers onsite. Early experiences with commercial sources were not consistent, so most work to date has been with sidestream production onsite (USEPA, 2008a). Two patented sidestream configurations for external bioaugmentation are the Single reactor High-activity Ammonia Removal over Nitrite (SHARON) process and the In-Nitri® process. Both provide high temperature sidestream nitrification using ammonia from the anaerobically digested sludge dewatering liquid or digested supernatant. The nitrifiers grown in the sidestream reactor are fed to the main liquid treatment stream.

Both use flow through reactors with hydraulic retention times (HRT) in the 2 to 3 day range. In the SHARON process, nitrification is stopped mainly at nitrite by such process control methods as low DO concentration, low pH and/or low SRT. Full-scale operating systems for the SHARON process include installations at Utrecht, Rotterdam, Zwolle, Beverwijk, Groningen, The Hague in the Netherlands, and a system in New York City. Seeding from a diffused air biological nutrient removal process to stimulate nitrification in a parallel oxygen process has proved successful at a number of locations (Bott et al., 2007). Emerging *in situ* bioaugmentation technologies used to enhance nitrifier growth and shown to be successful in bench, pilot, and/or full-scale trials are described briefly below (USEPA, 2008a):

- The Bio-Augmentation Regeneration/Reaeration (BAR) process was developed in the U.S. and is identical to the Regeneration-DeNitrification (R-DN) process developed independently in the Czech Republic. It works by recycling ammonia-laden filtrate or centrate from dewatering of aerobically digested sludge to the head of the aeration tank. The sidestream is fully nitrified, seeding the aeration tank with additional nitrifying bacteria which allows for reduced SRT.
- Aeration Tank 3 (AT3) is similar to the BAR process except that it sends a smaller fraction of the return activated sludge (RAS) to the aeration tank in order to stop the nitrification process at the nitrite stage.
- Bio-Augmentation Batch Enhanced (BABE) process uses a SBR to grow nitrifiers by feeding it RAS and reject water from the sludge dewatering process. After treatment, concentrated nitrifiers are recycled to the head of the aeration tank.

- The Mainstream Autotrophic Recycle Enhanced N-removal (MAUREEN) Process was developed for the two-sludge treatment configuration at the Blue Plains Advanced Wastewater Treatment Plant in Washington, DC. The process involves sidestream treatment of WAS from the second stage to preferentially select AOB for bioaugmentation to the first sludge stage.

Attached Growth Nitrification

Attached growth processes will also nitrify. Trickling filters and rotating biological contactors (RBCs) have historically been used for biological treatment of wastewater and can achieve nitrification with a low organic loading and a relatively high media volume. Typically, nitrification is achieved on the media after most of the BOD is removed since the heterotrophic population competes with the nitrifying organisms for oxygen and space on the media.

A major disadvantage of these technologies compared to suspended growth systems is that denitrification is fully dependent on addition of a supplemental carbon source. Suspended growth processes, on the other hand, can be designed to denitrify 80 percent or more of nitrate using the incoming BOD as the carbon source, which is a lower cost solution.

Consequently, trickling filters and RBCs have fallen out of favor for nutrient removal applications. In recent years, manufacturers have developed new technologies called biological aerated filters (BAF) to achieve BOD removal and nitrification. USEPA (2008a) identifies two existing BAF designs as established technologies: the Biofor® system and the Biostyr® system. The Biofor® filtration system is a fixed bed, upflow system with a dense granular media that is designed to expand during filtration. Air is sprayed into the filter to maintain an aerobic environment. The Biostyr® system is similar but uses a media that is less dense than water and held in place during operation by a screen at the top of the cell.

BAF can be configured in series to remove BOD in one unit and ammonia-nitrogen in the next or it can be designed for BOD removal and nitrification in a single unit depending on process goals. Advantages of BAF include its smaller footprint, higher hydraulic loading rates, and less susceptibility to washout than suspended sludge systems (Verma et al., 2006).

Another fixed film process that has gained popularity lately is moving bed biofilm reactors (MBBR). These reactors involve biofilm attached to a plastic media in a series of fluidized bed reactors. The plastic media help promote specialization of the biofilm within each reactor for either nitrification or denitrification (WEF and ASCE, 2006). Mixers or medium bubble diffuse aeration are used to keep the media suspended, depending on whether the system is anaerobic or aerobic. MBBR has a shorter SRT and smaller footprint than activated sludge processes. It has also proven to be effective in cold temperatures (Bott et al., 2007).

Separate-Stage Denitrification

A separate-stage denitrification system may be appropriate for plants that are regularly achieving nitrification and need to add denitrification capabilities. Attached growth systems (denitrifying filters) are more common than suspended growth systems, although suspended growth systems have been used for some treatment plants. Suspended growth reactors typically have short SRTs (2 to 3 hrs) and a small aerated zone following the denitrification zone to oxidize excess methanol and release contained nitrogen gas bubbles (WEF and ASCE, 2006).

Denitrification filters typically have a small footprint compared to suspended growth systems and have the added advantage of achieving denitrification and solids removal simultaneously. They were first installed in the 1970s and have evolved into two main process configurations (USEPA, 2007c):

- Downflow denitrification filters are deep bed filters consisting of media, support gravel, and a block underdrain system. Wastewater flow is directed over weirs onto the top of the filter where a supplemental carbon source, typically methanol, is added. Backwashing (typically air scouring and backwashing with air and water) is conducted at regular intervals to remove entrapped solids from the filter. During operation, nitrate is converted to nitrogen gas and becomes entrained in the filter media, increasing head loss through the filter. To release entrained nitrogen, most denitrification systems have a nitrogen-release cycle operation that essentially “bumps” the filter by turning on the backwash pump(s) for a short period of time.

- Upflow continuous backflow filters do not have to be taken off-line for backwashing, as it is an integral part of the filtering process. Wastewater enters the bottom of the filter where a carbon source, typically methanol, is added. Water flows up through an influent pipe and is dispersed into the filter media through distributors. Filtered water discharges at the top of the filter. Filter media continuously travels downward, is drawn into an airlift pipe at the center of the filter, and is scoured before being returned to the filter bed.

Performance of denitrifying filters depends on many factors including:

- Influent weir configuration
- Filter media
- Underdrain system
- Backwash system
- Flow and methanol feed control

One wastewater system in Connecticut reported that key design issues for them were influent piping design to minimize aeration, maintaining a consistent flow to the filters, and control of methanol feed based on influent COD (Pearson et al., 2008).

Key Design and Operational Issues

Temperature

In general, as temperature of the wastewater increases, the rate of nitrification and denitrification increases. For the typical range of liquid temperatures between 10 and 25° C, the nitrification rate will approximately double for every 8 to 10° C increase in temperature (WEF and ASCE, 2006). Rapid decreases in temperature without acclimation time will, however, cause even slower nitrification rates than predicted, strictly by the temperature change. Denitrification rates will also increase with increasing temperature, although not at the same magnitude as nitrification rates.

Dissolved Oxygen

Nitrifying bacteria are also more sensitive to DO levels as compared to aerobic heterotrophic bacteria, with growth rates starting to decline below 3 to 4 mg/L with significant reduction below 2 mg/L. The nitrification rate at a DO concentration of 0.50 mg/L is only about 60 percent of that at a 2.0 mg/L DO concentration. Studies have shown that the amount of oxygen available to nitrifying bacteria can be limited by floc size, requiring higher bulk DO concentrations under higher organic loading conditions (Stenstrom and Song, 1991). At DO concentrations less than 0.5 mg/L, the effect is greater for *Nitrobacter* than for *Nitrosomonas*. This can result in higher NO₂-N in the effluent and have a negative impact on chlorine disinfection as 1 g of NO₂-N consumes 5 g chlorine for oxidation. DO must normally be less than 0.2 to 0.5 mg/L, otherwise there will be inhibition of the denitrification process.

pH and Alkalinity

Nitrification generally operates well within a pH range of 6.8 to 8.0 (WEF and ASCE, 2006). At lower pH values the nitrification rate is much slower and at pH values near 6.0 the nitrification rate may only be about 20 percent of that with a pH of 7.0 (Tchobanoglous et al., 2003). Alkalinity is consumed during the nitrification process but partially replenished (up to 62.5 percent) during the denitrification process. Depending on the influent wastewater alkalinity, there may be a sufficient alkalinity reduction due to nitrification to decrease to unacceptable levels. Addition of chemicals such as lime, sodium hydroxide, or soda ash can be used to replace the alkalinity consumed by nitrification to maintain acceptable pH levels.

Carbon Sources for Denitrification

Denitrifying bacteria need a readily available carbon food source, such as soluble BOD, to ultimately convert nitrate to nitrogen gas. WWTPs that meet very low total nitrogen limits typically use a secondary anoxic zone in which supplemental carbon is added. Supplemental sources can be “internal” such as fermented wastewater or sludge, or “external” sources such as purchased chemicals.

Methanol is currently the most common external carbon source used in denitrification because of its low cost. It has several drawbacks, however, namely:

- It is highly flammable and implicated in some storage tank explosions and fires (Dolan, 2007); however with proper design and operation problems can be minimized.
- It is not the most efficient source for most treatment configurations.
- Costs have begun to fluctuate widely (deBarbadillo et al., 2008).
- Availability is a problem in some areas (Neethling et al. 2008).
- Reported low growth rates under cold temperatures (Dold et al. 2008).

Other sources of carbon include ethanol, acetic acid, corn syrup, molasses, glucose, glycerol, and industrial waste products. The WEF Nutrient Challenge Research Plan (2007) identified research on alternative carbon sources as priority for operators, owners, and engineers of wastewater systems. In December of 2007, the 2nd External Carbon Workshop was held in Washington, DC to discuss the state of the technology and research needs. WERF is also currently formulating a standard protocol for evaluation of external carbon alternatives.

Nitrification Inhibition from Toxic Chemicals

Nitrifying bacteria are very sensitive to heavy metals and other inorganic compounds in waste-water. The Local Limits Development Guidance Manual (USEPA 2004) has been the main source of information on inhibitory effects for a variety of wastewater treatment processes including nitrification. Appendix G of the 2004 version provides a summary table with the reported range of nitrification inhibition threshold levels for a number of metals, non-metal inorganics, and organic compounds. Actual inhibitory effects are site-specific and depend on many factors including the nature of biodegradable organic material, microorganism speciation, acclimation effects, temperature, and water quality conditions.

Wet Weather Events

Wet weather events can increase inflow and infiltration into the collection system and subsequently increase the hydraulic load to the wastewater treatment plant. This can in turn reduce the SRT leading to reduced performance of nitrification process units. In addition, wet weather flows have different characteristics than typical wastewater influent flow and can be less favorable for nitrification and denitrification. Conditions that are less favorable for nitrification include decreased alkalinity and sudden temperature drops. Lower biodegradable COD concentrations and increased DO make wet weather flows less amenable to denitrification.

Flow equalization basins can be used to handle wet weather events; however, this requires available space and capital investment. USEPA (2008a) identifies a number of innovative storage and treatment technologies used to manage influent flows during wet weather events.

Guidance for Selecting Process Modifications

Nitrogen removal requires first that a biological nitrification process be present or that the facility be modified to accomplish nitrification. Considerably more volume is needed for activated sludge nitrification compared to designs for BOD removal only. If there is insufficient space to accommodate the increased volume, suspended growth or hybrid process options that require less space such as the MBR process or IFAS systems with suspended media in the activated sludge process should be considered. Another option is to use a fixed film nitrification process after the suspended growth process clarification step. This could be a BAF or a plastic media trickling filter. However, if nitrogen removal is required, an exogenous carbon source is needed, which has higher operating costs than using the influent BOD for denitrification.

Nitrification systems need sufficient oxygen transfer for ammonia oxidation in addition to BOD removal. Such systems should consider the impact to diurnal loadings and ammonia addition in recycle streams. The influent TN concentration may have daily peak values that are 1.5 to 2.0 times the daily average loading. Higher peak loadings require longer SRTs to assure that sufficient nitrifying bacteria are present to remove ammonia at a greater rate, while maintaining a low effluent ammonia concentration. Often anaerobic digester sludge dewatering operations occur during the day and produce return recycle streams high in ammonia concentration (500-1000 mg/L) at times that coincide with the high influent diurnal ammonia loads. Recycle equalization or treatment helps to provide a more stable nitrification system and lower effluent NH₃-N concentrations.

In many cases, it is advantageous to incorporate a denitrification pre-anoxic step with nitrification (MLE process) due to the many benefits and improved operational stability. The advantages include

- 1) less aeration energy as the nitrate produced can be used for BOD removal,
- 2) the production of alkalinity to offset the alkalinity used by nitrification, which in some cases eliminates the need to purchase alkalinity, and
- 3) a more stable, better settling activated sludge process as the anoxic-aerobic processes favor good settling floc-forming bacteria over filamentous growth.

The effluent nitrogen goals greatly affect the process design choices and system operation. For an effluent goal of 10 mg/L TN, an MLE process is often sufficient for activated sludge treatment with secondary clarifiers or membrane separation. However, with water conservation leading to more concentrated wastewater, these processes alone may not be sufficient due to the fact that they are limited to 80-85% removal of the influent TN.

For TN effluent goals of 3 to 5 mg/L or lower, some form of post anoxic treatment is generally needed. One option is to convert an MLE process to a Bardenpho process by adding another anoxic aerobic set of tanks. Although the endogenous respiration rate of the bacteria can be used to consume nitrate in the post anoxic tanks, it is often necessary to add an exogenous carbon source. Other alternatives to using exogenous carbon sources include denitrification filters instead of adding more activated sludge tank volume, step feed with carbon addition in the last pass, and IFAS processes.

Denitrification processes require sufficient carbon to drive the nitrate/nitrite reduction reactions. Characterization of the influent wastewater with regard to its organic strength and soluble fraction and the TN and ammonia concentrations is needed to fully understand a system's carbon needs. In addition, design and operating methods that eliminate or minimize DO feeding to anoxic zones can reduce the amount of exogenous carbon needed and provide a more stable operation. Low DO zones prior to downstream anoxic tanks or for withdrawal of recycle to preanoxic zones should be considered.

Impacts on Sludge Production and Handling

It has been documented by both research and full scale experiments that BOD removal by activated sludge using nitrate as the electron acceptor instead of DO will result in a 20% or more reduction in waste activated sludge (WAS) production for the same operating conditions. Full-scale investigations near Melbourne, Australia achieved as high as a 40% reduction in WAS, and implementation of nitrogen removal at the York River, VA, plant resulted in a reduction of more than 50% in WAS production. The impact this will have on total sludge production by a treatment plant will depend upon how much waste sludge is produced by other treatment units such as primary clarifiers and chemical treatment with precipitating chemicals.

Additionally, implementation of nitrogen removal at conventional activated sludge plants can improve the thickening characteristics due to decreasing the amounts of filamentous bacteria in the activated sludge. If an external carbon source is added to improve the rate of denitrification, there will be an increase in WAS production compared to when no external carbon source is added. If an external carbon source is used to supplement denitrification, it is likely that the small increase in solids production will be offset by endogenous respiration due to longer SRTs. Solids produced from nitrogen removal processes generally thicken and dewater well and show no negative impact on any solids processing system.

Biological Phosphorus Removal and Combination Processes

This section provides an overview of the principles behind biological phosphorus removal (BPR). It describes existing configurations that can achieve phosphorus removal and in many cases, simultaneous nitrogen removal. Key operational issues, impacts on sludge handling, and a summary of ongoing research related to BPR removal are also provided.

Principles

Biological phosphorus removal is achieved by contacting phosphorus accumulating organisms (PAOs) in the RAS with feed, containing volatile fatty acids (VFA), in a zone free of nitrates and DO (anaerobic zone). Phosphorus is released in this zone providing energy for uptake of VFAs that are polymerized and stored inside the PAO cells. The anaerobic zone is followed by an aeration zone where the polymerized VFAs are metabolized and phosphorus is taken up again to store excess energy from the metabolism.

The phosphorus content of the mixed liquor suspended solids (MLSS) would be similar to that of the waste activated sludge (WAS). When nitrification occurs in the aeration basin, nitrates will be present in the RAS, resulting in some metabolism of the VFA before storage, thereby reducing subsequent phosphorus uptake. Some form of denitrification (anoxic zones) must be used to reduce/remove the nitrates from the RAS. The process flow sheets now known as Pho-redox (A/O) and 3 Stage Pho-redox (A²/O) as well as the modified Bardenpho process were first published by Barnard (1975) as the Pho-redox flow sheets for the removal of phosphorus. The theory for the functioning of the PAO was first suggested by Fuhs & Chen (1975).

Fuhs & Chen Theory

PAOs have the ability to store a large mass of phosphorus in their cells in the form of polyphosphates. Polyphosphates are formed by a series of high-energy bonds. The organisms can subsequently get energy from breaking these bonds. The polyphosphate globules within the cells function just like energy storage batteries. The storage of polyphosphates (energy), takes place in the aeration zone. In the anaerobic zone, these obligate aerobic bacteria can take up short chain VFA such as acetate and propionate and store them in the form of intermediate products such as poly- β -hydroxybutyrate (PHB). The energy for transferring the food across the cell membranes in the anaerobic zone is derived from breaking phosphorus bonds. Excess phosphates are released to the liquid in the anaerobic zone.

Some magnesium and potassium ions are co-transported across the cell walls with phosphates. PAOs can only get energy from the food they have taken up in the anaerobic zone when they pass to the aerobic zone where oxygen is available. They use oxygen to metabolize the stored products, deriving enough energy to take up all the released phosphates as well as those in the influent, and store them in the cells. The WAS will contain sufficient phosphate-enriched PAOs to remove most of the phosphorus from the waste stream once enhanced BPR is established.

The right carbon source, in this case a combination of acetates and propionates, is essential for BPR. The wastewater characteristics are thus important. In general, it can be said that you need at least 40:1 COD:TP or about 18:1 BOD₅:TP in the process influent wastewater to reduce effluent phosphorus to less than 1.0 mg/L. In addition, some of the COD should consist of short chain VFAs. More COD may be required if nitrates must also be denitrified.

Biological phosphorus removal can work in with or without nitrification. When nitrification occurs, denitrification within the process is important to reduce the nitrates that may be returned with the RAS. While the anaerobic zone serves mostly as a contact zone for VFAs and PAOs, some fermentation of easily biodegradable carbon compounds (rbCOD) to acetate and propionate may take place. In most plants the readily biodegradable material is in short supply and must be reserved for the PAOs.

When nitrate or oxygen is discharged to the anaerobic zone, two things may happen, both undesirable:

- They will prevent fermentation of rbCOD to acetic and propionic acid.
- Nitrates or DO could serve as electron acceptors for PAOs and other organisms that will metabolize the VFA and so deprive the PAOs of the substance that they need to store for growth and phosphorus removal.

In the absence of electron acceptors such as DO and nitrates in the anaerobic zone, PAOs are favored to grow since they can take up and store the VFA under anaerobic conditions, thereby making it unavailable for other aerobic and facultative heterotrophs in the aerobic zone.

Biological removal of both nitrogen and phosphorus at the same WWTP is common. Both functions require a carbon source. While denitrification organisms can feed on quite a number of easily degradable materials such as methanol, sugar, glucose, acetate and propionate, PAOs are restricted to the latter two for polymerization and storage (e.g. adding methanol to the anaerobic zone will reduce nitrates but not assist in the removal of phosphorus).

Current Configurations

The basic design of anaerobic, anoxic, and aerobic zones, in that order, has been achieved in many different configurations. The configurations vary in the number of stages, the nature and location of recycles, and the operation of the process. Each process was modified from the standard biological activated sludge design in order to accomplish various design goals (e.g., protection of the anaerobic zone from excess nitrate recycle). The primary processes are listed below.

Of these, all will also biologically remove nitrogen except for the Pho-redox process.

- Pho-redox (A/O)
- 3 Stage Pho-redox (A₂/O)
- Modified Bardenpho
- University of Capetown (UCT) and Modified UCT (MUCT)
- Johannesburg (JHB), Modified Johannesburg, and Westbank
- Orange Water and Sewer Authority (OWASA)
- Oxidation ditches with anaerobic zones or phases added
- SBR operated with an anaerobic phase
- Hybrid chemical/biological processes

The performance of these technologies depends on many site specific factors, including but not limited to temperature, hydraulic and organic loading, recycle rates, and return streams. The technologies described in this section are generally capable of phosphorus removal to effluent levels between 0.5 and 1.0 mg/L. Operating strategies that can be used to enhance biological treatment and achieve these and, in some cases, even lower effluent levels.

Biological phosphorus removal can be combined with other technologies to achieve very low effluent concentrations (< 0.2 mg/L). Chemical addition combined with biological removal of phosphorus has been used to consistently achieve low levels. WEF and ASCE (1998) recommend that WWTPs have chemical addition capabilities even for well operating BPR plants to provide backup phosphorus removal in the event of power outages, pipe breaks, or other unforeseen events.

Solids removal can also be a limiting factor in achieving phosphorus removal below 0.2 mg/L. Very low phosphorus levels generally require a TSS level of less than 5 mg/L. Tertiary filtration (see membrane bioreactors), and advanced clarification processes can achieve TSS levels less than 5 mg/L.

Pho-redox (A/O) and 3 Stage Pho-redox (A₂/O)

The Pho-redox (A/O) process is a conventional activated sludge system with an anaerobic zone at the head of the aeration basin. The RAS is pumped from the clarifier to the anaerobic zone. It is a low SRT process, operated to avoid nitrification. With no nitrates in the RAS the process is reliable and easy to operate except at temperatures in excess of 25°C when nitrification is difficult to avoid. The 3 Stage Pho-redox (A₂/O) process adds an anoxic zone after the anaerobic zone to achieve de-nitrification.

In addition, a nitrate rich liquor is recycled from the end of the aerobic zone to the head of the anoxic zone to enhance de-nitrification. A shortcoming of the 3 Stage Pho-redox process is that there will be nitrates present in the RAS, potentially making the process unreliable.

Modified Bardenpho

The Bardenpho process removes nitrogen to low concentrations. The addition of an anaerobic zone at the head of the process enables phosphorus removal as well. The process consists of 5 stages: an anaerobic stage followed by alternating anoxic and aerobic stages. A nitrate-rich liquor is recycled from the first aerobic stage, designed for complete nitrification, to the first anoxic stage. The RAS is recycled from the clarifier to the beginning of the anaerobic zone. Since the nitrates in the RAS ranges from 1 to 3 mg/L, it does not seriously interfere with the mechanism for phosphorus removal as can happen in the 3 Stage Pho-redox process.

University of Cape Town (UCT) and Modified UCT (MUCT)

The UCT process was designed to reduce nitrates to the anaerobic zone when high removal of nitrates in the effluent is not required. It consists of three stages: an anaerobic stage, an anoxic stage, and an aerobic stage. The RAS is returned from the clarifier to the anoxic zone instead of the anaerobic zone to allow for denitrification and to avoid interference from nitrate with the activation of the PAOs in the anaerobic stage. A nitrate rich stream is recycled from the aerobic zone to the anoxic zone. Denitrified mixed liquor is recycled from the anoxic zone to the anaerobic zone. Several modifications of the process exist. Sometimes it can be difficult to achieve the level of denitrification in the anoxic zone required to protect the anaerobic zone from nitrates when the zone is receiving both RAS and high internal nitrate recycle flows. This problem led to the development of the modified UCT process, which splits the anoxic zone into two stages. The nitrate rich recycle from the aerobic zone is recycled to the head of the second anoxic stage. The nitrate containing RAS is recycled to the first anoxic stage where it is denitrified. Next, the denitrified RAS is recycled from the end of the first anoxic stage back to the head of the anaerobic stage and mixed with the incoming wastewater.

Johannesburg (JHB), Modified Johannesburg and Westbank

The JHB process is similar to the 3 Stage Pho-redox process, but has a pre-anoxic tank ahead of the anaerobic zone to protect the zone from nitrates when low effluent nitrates are not required. The low COD of the wastewater limited the de-nitrification capacity in the original plant (Nothorn Works), resulting in nitrates in the RAS. This reduced BPR so much that a pre-anoxic tank was included on the RAS line to remove the nitrates from the RAS flow using endogenous respiration, before the flow entered the anaerobic zone. The modified JHB process adds a recycle from the end of the anaerobic zone to the head of the pre-anoxic zone to provide residual, readily biodegradable compounds for denitrification.

The Westbank process is similar to the JHB process but adds some primary effluent to the anaerobic zone to assist in denitrification with the remainder of the primary effluent being discharged to the anaerobic zone. During storm flows, excess flow is passed directly to the main anoxic zone. VFA obtained from acid fermentation of the primary sludge is passed to the anaerobic zone.

Orange Water and Sewer Authority (OWASA)

The OWASA process was developed by adding activated sludge from a biological nitrogen removal process to a trickling filter plant. Then, nitrified effluent from the trickling filter is fed to the aerobic zone of the activated sludge system. Because the VFAs have been destroyed by the trickling filter, it is necessary to ferment the settled organic solids from the primary clarifier to produce sufficient VFAs for BPR.

Next, the fermented supernatant is passed to an anaerobic (nutrition) zone and mixed with the RAS to initiate BPR. Mixed liquor then flows from the nutrition zone to an anoxic zone and then to an aerobic zone. Alternatively, simultaneous nitrification and denitrification takes place in the aeration zone.

Oxidation Ditches

There are several oxidation ditch designs that can remove phosphorus. They normally consist of an anaerobic zone ahead of the oxidation ditch whereas simultaneous nitrification and denitrification takes place within the ditches. Oxidation ditches typically operate as racetrack configurations around a central barrier, with forward mixed liquor flows of approximately 1 foot per second or more. It is possible, by manipulating the DO transferred to the mixed liquor, to establish both anoxic, aerobic and near anaerobic zones within the racetrack configuration, even though the high flow velocities accomplish complete mixing of the wastewater with the RAS.

There are many forms of oxidation ditches, such as the Carousel, the Pasveer Ditch and the Orbal process. The Orbal process creates anaerobic and anoxic zones in the outer of three concentric oval shaped ditches with the RAS recycled from the clarifier to the anoxic zone. It is also possible to introduce an anaerobic tank before the ditch to accomplish BPR in the combined system. The Pasveer Ditch and the Carousel system also can be used in conjunction with an anaerobic zone to accomplish BPR, in addition to simultaneous nitrification and denitrification within the ditches.

Because of the very high internal recycle within the ditches, very low nitrate concentrations can be achieved in the mixed liquor before settling, and anaerobic conditions are easy to maintain in the anaerobic zone, thereby resulting in efficient BPR. The layout would resemble a Pho-redox process with simultaneous nitrification-denitrification (SND) in the aeration basin. Alternatively the Carousel or Pasveer Ditch could be used as the aeration stage in either the 3 Stage Pho-redox or the Modified Bardenpho process.

The VT2 process at Bowie, MD, operates two Pasveer ditches in series with dedicated anoxic, near anaerobic and aerobic zones. It also has a side stream anaerobic zone that receives only 30 percent of the influent flow to enhance BPR. Denitrified MLSS for the anaerobic zone are obtained from the end of the near anaerobic zone of the adjacent ditch. Operated without primary sedimentation, the system consistently obtains very low (<0.25 mg/L) effluent TP without chemicals or effluent filtration. The ditches are operated in series because the plant has limited clarification capacity, and series operation results in lower MLSS concentrations to the clarifiers. The bardenpho process also uses pairs of ditches. The ditches in the bardenpho process operate in alternating anoxic-aerobic modes. An anaerobic tank is placed before the ditches for BPR and the ditches are alternated between nitrification and denitrification.

Sequencing Batch Reactors (SBR)

SBRs are fill-and-draw reactors that operate sequentially through the various phases by means of adjusting the mixing and aeration. The reactor phases can be set and automated to allow the mixed liquor to go through an anaerobic/anoxic/aerobic progression as is necessary for removal of phosphorus and nitrates. Because of the fill-and-draw nature of SBRs, it actually is necessary to remove the nitrates remaining from the previous cycle before anaerobic conditions can be established, thus the typical treatment progression becomes anoxic/anaerobic/aerobic. However, SBRs are almost always operated without primary sedimentation, so they still usually have a favorable BOD₅:TP ratio for effluent TP of somewhat less than 1.0 mg/L during the settling phase.

Hybrid Chemical / Biological Processes

The PhoStrip configuration, used mainly in non-nitrifying plants, pulls a side stream off the RAS in a conventional activated sludge plant. The side stream is concentrated and retained for a day or more in a thickening tank where the solids blanket is deep enough to produce anaerobic conditions and fermentation, resulting in the release of phosphates by the microorganisms. Lime is then added to the supernatant stream to precipitate and remove phosphate. The thickened, fermented sludge is passed back to the main aeration basin. Existing plants include Seneca Falls, NY; Lansdale, PA; Adrian, MI; Savage, MD; Southtowns, NY; Amherst, NY; and Reno-Sparks, NV.

The Biological Chemical Phosphorus and Nitrogen Removal (BCFS) configuration is similar to the modified UCT process. In this process, a sludge stream is removed from the anaerobic zone. Ferric chloride is added to the sludge thickener to remove phosphate. This provides an advantage over chemical addition to the secondary clarifier because it does not require the chemical sludge to be recycled. There is an existing plant at Holten in the Netherlands (WEF and ASCE, 2006), but no performance data are available.

Emerging Technologies

Many plants that are not specifically configured for BPR nevertheless achieve phosphorus removal to less than 1 mg/L. The first such observation in a nitrifying plant was in a four-stage Bardenpho plant where mixed liquor was recycled from the second anoxic zone to an unstirred fermenter, then returned to the anoxic zone. The CATABOL™ and Cannibal Processes claim to reduce excess secondary sludge production by passing mixed liquor or RAS through an anaerobic (fermenting) stage and then back to the main stream aeration system. In addition, both processes pass the mixed liquor through a process for removal of some of the inert solids. Both processes claim to get similar phosphorus removal to that for the Bardenpho plant described above.

All of these processes rely on the fermentation of some of the mixed liquor for producing VFA that assists in the biological removal of phosphorus. The Town of Cary, NC, has been using a system by which some of the sludge in the return streams of a biological nitrogen removal plant is subjected to anaerobic conditions similar to that of the other processes described above resulting in an effluent phosphorus concentration of less than 0.5mg/L. There is a similarity between these processes and *ad hoc* processes for switching off aeration in plug-flow plants for promoting phosphorus removal. These *ad hoc* processes take various forms. The Piney Water, CO, plant is a 5-stage Bardenpho plant with no primary sedimentation and little VFA in the influent, which resulted in little phosphorus removal. By switching off a mixer in one of the anaerobic zones, sludge settled to the bottom and fermented, which supplied the VFAs for reducing the orthophosphorus to less than 0.2 mg/L. A similar operation at the Henderson, NV, plant in a JHB type process had the same effect. Some plug-flow aeration plants succeeded in reducing phosphorus to below 1 mg/L by turning off aeration at the feed end of the plant, such as the Blue Lakes and Seneca plants operated by the Metropolitan Council Environmental Service in Minnesota and the St. Cloud, MN, plant.

The Joppatowne plant operated by Harford County, MD, consists of an MLE plant with some sludge accumulation in the anoxic zone while reducing the phosphorus from 7 mg/L in the influent to around 1 mg/L in the effluent. All of these plants use the same principle of fermenting some of the mixed liquor sludge or underflow from the final clarifiers, either inside the main stream tanks or in a side stream basin. There are many instances where enterprising operators can achieve 80 percent or more phosphorus removal by turning off air or mixers in conventional treatment plants. There is a Catabol plant in Cartersville, GA (USEPA, 2008a); however, there are no published data for this plant.

Operational and Design Considerations

Important factors that affect BPR include:

- Bioavailable COD:P ratio in the anaerobic zone influent, including adjustments by VFA addition and sludge fermentation
- SRT and HRT
- Presence of oxygen or nitrate in the anaerobic zone
- Backmixing of oxygen
- Temperature
- pH
- Secondary release under anaerobic conditions
- Sufficient oxygen in the aerobic zone
- Inhibition
- Flow and load balancing

COD:P Ratio

The PAOs need VFAs in the form of acetic and propionic acid. These acids may be in the feed or can be produced through fermentation of soluble rbCOD such as sugar, ethanol, etc., in the anaerobic zone. As a rough estimate of the propensity for phosphorus removal to an effluent concentration less than 1.0 mg/L, the COD:P ratio typically should be about 40 or more. VFA is produced through fermentation of municipal wastewater or it can be added as a commercial or waste product. Some wastewater collection systems that are relatively flat and have long collection times may have sufficient fermentation in the collection system to provide the necessary VFAs, but it will vary monthly depending upon the temperature and flow conditions in the collection system. Force mains are excellent fermenters for the production of VFA. Systems that do not have a COD/P ratio of at least 40 will most likely need to supplement VFAs to achieve effluent phosphorus concentrations below 1.0 mg/L. However, they will still achieve substantial BPR with lower ratios if appropriately operated. See below for a more detailed discussion of VFAs.

Recent studies suggest that the instantaneous COD:P ratio is more important than the overall average (Neethling et al., 2005). Short term drops in the BOD:P ratio in the primary effluent to below that required for sustainable phosphorus removal correlated well with rises in effluent phosphorus. Intermittent recycles of phosphorus rich return streams may cause short term variability in the BOD:P ratio. Controlling or eliminating these recycles can improve plant performance. Weekend changes in the BOD:P ratio also can affect performance.

Another group of organisms, glycogen accumulating organisms (GAOs), also has the ability to take up acetate in the anaerobic zone, not by using energy in phosphate bonds but by using stored glycogen as the energy source. Under certain conditions, such as high temperatures or low phosphorus concentrations relative to the influent bioavailable COD, they may out-compete PAOs for the VFAs, which would result in less or no release of phosphorus in the anaerobic zone. This in turn will result in less or no overall phosphorus removal. GAOs use the stored energy in the form of glycogen to take up VFAs and store them as a complex carbohydrate containing poly-hydroxy valerate (PHV), instead of PHB formed with poly-phosphorus as the energy source. When this begins to happen, there is a slow decline of phosphorus removal by the biological system.

There is still a debate amongst researchers about the conditions likely to favor GAOs over PAOs. Summarizing a number of publications, it would appear that the following conditions favor the growth of GAOs over that of PAOs:

- High SRT
- High temperature over 28 °C
- Longer non-aerated zones
- Stronger wastes with low TKN content
- Periods of intermittent low BOD loads
- If the VFA consists mostly of either acetate or propionate
- Polysaccharides such as glucose are fed to the anaerobic zone.
- Low pH in the aerobic zone

Further confirmation is needed for some of these factors.

Volatile Fatty Acid Addition

Only VFAs such as acetic and propionic are taken up by PAOs. Reported doses of VFA for successful phosphorus removal range from 3 to 20 mg/L VFA per gram of phosphorus removed. These numbers, however, do not take into account the rbCOD that is fermented in the anaerobic zone. It is more accurate to look at the rbCOD/P ratio for good phosphorus removal, which ranges from 10 to 16. (Barnard, 2006). Surveys show that it is rare for a WWTP treating municipal sewage to achieve more than 95 percent removal of phosphorus by biological processes without adding VFAs (Neethling et al., 2005).

An Australian study shows that while both PAOs and GAOs could use acetate, PAOs will have a competitive advantage when the VFAs consist of roughly equal parts of acetic and propionic acid as a growth medium. PAOs that are fed on acetate are able to switch to propionate much more quickly and effectively than GAOs (Oehmen et al., 2005). This finding led to a strategy to feed equal amounts of acetic acid and propionic acid as the optimal for stimulating PAO growth (Oehmen et al., 2006, Bott et al., 2007).

One study shows that isovaleric acid drives BPR even better than acetic acid (Bott et al., 2007). Isovaleric acid, however, is much more expensive than acetic acid and is more odorous. It also is not significantly generated in the primary sludge fermentation process. Addition of rbCOD such as sugars and alcohols containing two carbons or more can increase phosphorus uptake by PAOs when added to the anaerobic zone but may cause sludge bulking if dosed in excess (Jenkins and Harper, 2003).

Sludge Fermentation

Anaerobic fermentation produces VFA consisting mainly of acetic and propionic acid. Some configurations, such as the Westbank and OWASA configurations, make use of anaerobic fermentation of the primary sludge to provide VFAs to the nutrient removal process. A fermentation process, however, can be added to any configuration to provide VFAs, especially in areas where little fermentation takes place in the collection system. Fermentation of the primary sludge or the RAS will produce VFA. Primary sludge fermentation is used more frequently.

There are several primary sludge fermenter designs that can accomplish this. The simplest configuration involves allowing the formation of a thicker sludge blanket in the primary clarifier itself and returning some of the thickened sludge to either the primary clarifier or to a mixing tank ahead of the primary clarifier to allow elutriation of the VFA to the primary effluent. This is referred to as an activated primary sedimentation tank (Barnard, 1984). Another variation is to pump some sludge to a complete-mix tank ahead of the primary clarifier, to accomplish fermentation. The sludge is then passed to the primary clarifier for elutriation of the VFA. Both of these processes lead to an increased load on the primary clarifier and some VFA may be lost due to aeration between the primary clarifier and the anaerobic zone. Sludge age should also be controlled to prevent methanogenic bacteria from growing and converting the VFA to methane. Usually, a SRT less than 4 days is sufficient for this.

Alternative methods accomplish fermentation in a gravity sludge thickener by holding the sludge under anaerobic conditions for 4 to 8 days. The supernatant can then be fed directly to the anaerobic zone and a high load on the primary clarifier can be avoided. Thickening can either be accomplished with a single thickener or in two stages. The two-stage process can either be a complete mix tank, followed by a thickener or two thickeners in series. It has been shown that adding molasses or other sources of readily biodegradable COD can improve the performance of fermenters (Bott et al., 2007).

RAS can also be fermented in a side stream process. The fermentation zone is similar to the anaerobic or anoxic zone of many biological processes. RAS fermentation could be used in any BPR process, but is most common in processes without primary clarifiers. Research and experience have revealed some key design considerations for primary fermenters (WEF and ASCE, 2006). These processes can have high solids content and may need a positive displacement pump to operate properly. Because fermentation can lower the pH and produce carbon dioxide and hydrogen sulfide, corrosion resistant materials should be used. Odor control may also be necessary if hydrogen sulfide is produced. Monitoring of pH and oxidation reduction potential (ORP) may be desirable to control the process.

Retention Time

The concentration of phosphorus in the sludge typically increases as the SRT increases, although the impact is very small over the SRT range of 4 to 30 days. Efficient phosphorus uptake typically requires a minimum SRT of 3 to 4 days depending on temperature. Higher SRTs will not increase phosphorus uptake, given there is sufficient VFAs available. If SRT becomes too great, however, effluent quality can degrade. This can be due to release of phosphorus as biomass degrades (WEF and ASCE, 2006). Both anaerobic and aerobic HRT can affect the amount of phosphorus stored by PAOs. Sufficient time should be allowed for the formation of VFAs and storage of the Polyhydroxyalkanoates (PHAs) in the anaerobic zone, although the reactions are relatively fast. If the time is too short, phosphorus uptake in the aerobic zone will be lower than achievable because insufficient PHAs were stored in the anaerobic zone. It has been reported that the ratio of HRT in the anaerobic zone to the HRT in the aerobic zone is important. One study found that a ratio of between 3 and 4 for aerobic HRT to anaerobic HRT led to optimal plant operation (Neethling et al., 2005).

Temperature

High temperatures can have an adverse effect on phosphorus removal. At temperatures greater than 28° C, phosphorus removal will generally be impaired, apparently by the predominance of the GAOs (Bott et al., 2007). At the low end of the temperature scale, Erdal et al. (2002) found that PAOs outcompeted GAOs at 5° C even though the PAO metabolism was slower at 5° C than at 20° C. The GAOs virtually disappeared in the 5° C reactor. Modeling studies have shown that GAOs can predominate at higher temperatures because of their increased ability to uptake acetate at those temperatures compared to PAOs (Whang et al., 2007). Low temperatures can also lower phosphorus uptake but have been shown to not be an issue in well operated and properly acclimatized plants (WEF and ASCE, 2006).

Presence of Oxygen or Nitrate in the Aerobic Zone

If oxygen or nitrate is present in the anaerobic zone, organisms that use oxygen or nitrates as electron acceptors will preferentially grow by fully oxidizing the organics to CO₂ and H₂O, thereby reducing the VFAs available for polymerization and storage by the PAOs. Nitrate can also inhibit fermentation of rbCOD because most of the fermenters are facultative and can use the nitrate as an electron acceptor to fully oxidize the rbCOD instead of producing VFAs as an end product of fermentation, thus depriving the PAOs of organics they can polymerize and store. Therefore, recycle of streams containing high DO and nitrate concentrations to the anaerobic zone should be avoided. Introduction of oxygen through pumps and other devices should also be avoided.

Avoiding Backmixing of Oxygen

Another potential source of oxygen and nitrates to the anaerobic zone is backmixing from downstream zones. In configurations where the anaerobic zone is followed immediately by an anoxic or aerobic zone, backmixing can cause elevated concentrations of nitrates and/or DO in the anaerobic zone leading to favoring of organisms other than PAOs. The problem can be avoided by increased baffling or changing the mixing rates. This problem is more likely to occur when the downstream zone is aerated, because aeration of mixed liquor increases the liquid depth, making the liquid level in the aerobic zone higher than in the non-aerated zone.

pH

Low pH can reduce and even prevent BPR. Below pH 6.9 the process has been shown to decline in efficiency (WEF and ASCE, 2006). This is possibly due to competition with GAOs. Filipe, et al. (2001), found that GAOs grow faster than PAOs at a pH of less than 7.25. Because many wastewater processes such as chemical addition and nitrification can lower pH, this should be monitored and adjusted if necessary. It also has been shown that it is not possible to establish enhanced biological phosphorus removal (EBPR) when the pH is less than 5.5, even though an abundant amount of acetic acid is present in the anaerobic zone (Tracy and Flammino, 1987; Randall and Chapin, 1997).

Anaerobic Release

Secondary release of phosphorus occurs when the PAOs are under anaerobic conditions in the absence of a source of VFA. The energy stored as polyphosphate is used for cell maintenance and phosphorus is released to the liquid phase (Barnard, 1984). There will then be no stored food to supply energy for the uptake of phosphorus upon subsequent aeration.

This may occur in the following process stages:

- In the anaerobic zone if the retention time is too high and the VFA is depleted well within the required retention time.
- In the main anoxic zone when that runs out of nitrates.
- In the second anoxic zone there are no nitrates to be removed.
- In the sludge blankets of final clarifiers when the RAS rate is too low and sludge is not removed fast enough.

Additionally, release may happen in aerobic zones that are too large, resulting in stored substrate depletion and destruction of PAO cells by endogenous metabolism. Since there was no food storage associated with the phosphorus release, additional carbon is then required to take up the phosphorus released, but the amount in the influent may be insufficient.

Therefore, chemicals must be added to remove the excess phosphorus. Over-design of biological nutrient removal systems could thus lead to a higher demand for an external source of VFA. Phosphorus will be released in sludge treatment processes that are anaerobic. Gravity thickening of BPR sludge can lead to phosphorus release if long retention times are used. Using mechanical dewatering instead of gravity dewatering allows less retention time and less phosphorus release (Bott et al., 2007). It is usually recommended that dissolved air flotation (DAF) be used to thicken BPR sludge to reduce the amount of phosphorus release. DAF thickening can be quite successful for the reduction of release, but if the thickened sludge is left on the DAF beach too long before removal, excessive release will occur, just as it will when the sludge is left too long in a gravity thickener.

Anaerobic digestion will also lead to phosphorus release although some phosphorus will be precipitated as either a metal salt (e.g. calcium phosphate) or as struvite (magnesium ammonium phosphate, $MgNH_4PO_4$). BPR sludge takes up and releases magnesium along with phosphates, and these two ions combine with ammonium, also present in abundance in anaerobic digesters, to form struvite.

Struvite formation is very fast, and will continue until one of the three ions is reduced to that ion's solubility level. Magnesium is usually present in the lowest concentration, and its depletion typically limits struvite formation within the anaerobic digester. Calcium phosphate precipitates also tend to form in anaerobic digesters, but they form much more slowly than struvite and the formation tends to be non-stoichiometric. If substantial amounts of phosphates are precipitated by calcium along with the struvite formation, there will be little if any propensity for struvite to form when the sludge exits the anaerobic digesters. Also, if the digested sludge is composted after dewatering, the resulting Class A sludge will be enriched in magnesium, phosphorus, nitrogen, and, to a lesser extent, potassium, which also is taken up and released with phosphorus by PAOs. Thirty percent of the phosphorus entering the anaerobic digesters at the York River plant during BPR experimentation was recycled back to the headworks from belt filter press dewatering (Randall et al., 1992).

Alternatives to anaerobic digestion such as composting, drying, or alkaline treatment can be used to reduce phosphorus release. There have been several studies which have examined using struvite precipitation as a way of recovering phosphorus from supernatant from digesters. These processes have been tested on full scale facilities in Treviso, Italy and Vancouver, Canada (SCOPE, 2004).

When anaerobic release of phosphorus occurs, recycling these streams can overload phosphorus removal processes. The effect can be worsened when the waste handling process is only operated intermittently. In some instances there is a high degree of phosphorus precipitation in the anaerobic digesters and with sufficient VFA in the influent the returned phosphorus may be removed. However, in most circumstances, some chemicals need to be added to the return streams or to the anaerobic digester itself so that the metal precipitate will be removed with the dewatered sludge.

Sufficient Oxygen in the Aerobic Zone

It is necessary for oxygen to be present in the aerobic zone for phosphorus to be taken up and retained in the activated sludge. Maintaining a sufficiently high DO transfer in the aerobic zone enhances process stability and has been found to be a key factor in phosphorus removal. (Bott et al., 2007)

Inhibition

EBPR, like any biological process, can be inhibited by chemicals toxic to the organisms. Although not as sensitive to inhibition as nitrification and rare in practice, the BPR process can be inhibited by toxic chemicals, including high concentrations of acetate (Randall and Chapin, 1997).

Flow and Load Balancing

Flows and loads to wastewater treatment plants can vary widely because of regular diurnal use patterns and because of larger, more irregular disturbances such as storm events. Peaks in either flow, or nutrient load can stress the system and cause poor performance. Peaks can be evened out using equalization tanks to balance the flow. Equalization tanks in combination with nutrient sensors can also be used to balance nutrient loads. In this case, recycle streams high in nutrient concentrations such as digester supernatant can be stored during peak nutrient loads and recycled during times when concentrations are lower.

Impacts on Sludge Handling and Removal

Stored phosphorus adds dry weight to the sludge; however, the actual PAO VSS production will be less because the reaction is less efficient than heterotrophic metabolism using DO as the electron acceptor. Sludge from BPR will be similar to sludge from conventional activated sludge plants, although it will have a higher phosphorus content. Varying results have been found with some plants reporting little or no change in settling and dewatering (Knocke et al., 1992) and others reporting enhanced settling and dewatering properties (Bott et al., 2007). The sludge produced from the process will also have higher magnesium and potassium concentrations due to co-uptake of these elements with phosphorus.

Struvite can precipitate in anaerobic processes. With abundant phosphorus and ammonia it is usually only the magnesium that is in short supply. Some magnesium is released from the digested cells with the phosphorus and may increase struvite precipitation. Some processes have proposed precipitating out struvite or other phosphate solids to avoid phosphorus return in recycle streams (Bott et al., 2007). The struvite crystals, however, depending upon where they form, can plug centrifuge ports, and pumps and pipes used to convey the sludge, if not controlled. Plugged lines are very difficult to clean.

Guidance for Selecting Process Modifications

If an existing activated sludge WWTP needs to lower phosphorus levels in its effluent, a number of options are available. Some key considerations are summarized below.

For systems that do not have BPR, an anaerobic zone can be added at the head of the plant. This may be achieved by switching off aerators at the head of the reactor or by adding a separate reactor. Mixing in the anaerobic zone should be sufficient to retain biological solids in suspension without introducing oxygen. If baffling is not already present, it could be added to achieve separation of the anaerobic and aerobic zones.

Note that baffling is essential to prevent backmixing because the liquid level in the aerated zone will always be higher than that in the non-aerated zone. Therefore, an overflow baffle should be used between zones. Considerations should also be made for additional pumping needed for any recycle streams. Proper sizing of the anaerobic zone is important to ensure sufficient VFA is formed and taken up in the aeration basin. If an aerobic zone is converted to an anaerobic zone, care should be taken to ensure that the remaining aerobic zone is sufficiently sized to achieve treatment objectives. This usually is not a problem because the anaerobic zone seldom needs to be more than 15 percent of the total volume, and can be considerably less if fermentation is practiced or VFA are added. Note that much of the BOD in typical municipal sewage will be removed from solution in the anaerobic zone, and this reduces the required size of the aerobic zone, even though most of the stored BOD will be stabilized in either the anoxic or aerobic zone, or both.

For plants that already have BPR but need additional phosphorus removal, the designers should start by identifying areas that may be limiting the current process. For example, if recycle streams are intermittent, overloading of the process may occur during recycle and the process performance may suffer. Flow equalization to enable constant recycle flows may be an option in these cases. RAS when returned to the anaerobic zone may introduce nitrates or oxygen that will interfere with PAO performance. The phosphorus content of the return streams could be reduced by adding some chemicals to precipitate some of the phosphorus. Reducing oxygen introduction to the anaerobic zone from upstream processes may be needed to optimize phosphorus removal.

Plants looking to improve phosphorus removal performance should also closely examine the plant for secondary release of phosphorus. If sludge blankets in clarifiers are too deep, anaerobic conditions can develop and cause secondary phosphorus release. This can be minimized by using deeper clarifiers, maintaining low sludge blankets, and increasing the RAS rate, so that the released phosphorus is pumped from the bottom of the clarifier rather than flowing over the effluent weir. Sludge handling can also cause excessive phosphorus release such as in gravity thickeners, DAFs and anaerobic digesters. If supernatant from these processes when poorly managed is recycled, it can overload the process. Options in this case would be to eliminate the recycle, improve operation of the process, change the process, or treat the recycle stream to remove phosphorus before it is returned to the plant.

Another area to examine in seeking improved phosphorus removal is the COD:P ratio. If the ratio is low, supplementing the current process with VFAs may provide additional removal. VFAs can either be added as a chemical addition process or produced through fermentation of primary or secondary sludge. Other ways of improving TP removal include filtration and chemical addition. Phosphorus is often attached to colloidal particles and very low phosphorus levels usually require removal of TSS. Membrane bioreactors (MBR) in combination with biological and/or chemical phosphorus removal can result in very low effluent levels due to enhanced solids removal. Chemical addition with or without filtration can also achieve low phosphorus levels.

Effluent Filtration

Effluent filtration in combination with chemical precipitation can be used to remove phosphorous down to very low levels (< 0.1 mg/L). USEPA Region 10 (2007) found that 2-stage filtration through use of a first and second stage filter or by providing tertiary clarification prior to filtration, resulted in the lowest effluent phosphorus concentrations of 23 WWTPs evaluated. Effluent filtration can also be used to remove soluble organic nitrogen that is not removed through biological treatment or settling.

A wide variety of filter types have been used for wastewater treatment, including:

- Conventional down-flow filters
- Deep-bed down-flow filters
- Continuous backwashing upflow sand filters
- Pulsed bed filters
- Traveling bridge filters
- Fuzzy filters
- Discfilter
- Cloth media disk filters
- Membranes
- Blue PROTM process
- Pressure filters

Types of Filters

This section describes the various filters listed on above page, presents key design and operating principles, and summarizes ongoing research and emerging technologies in this area.

Conventional Down-flow Filters

These filters consist of fixed-media beds typically up to 3 feet in depth and are similar to filters used to treat drinking water. Media can be single media, dual media, or multi media. Single media is typically sand or anthracite. Dual media combines anthracite and sand. Multi-media filters include a layer of garnet or limonite. Flow in these filters is by gravity from the top down. Most of the removal occurs in the top few inches of the media. The filter must be taken off-line periodically to backwash the filter to prevent clogging and too high of a pressure loss.

Deep-bed Down-flow Filters

These filters are similar to conventional down-flow filters but have deeper beds and larger media size. This gives the advantage of longer run times between backwashes. The size of the media is limited by the ability to backwash the filter. Because these filters are more difficult to backwash, air scour is necessary to fully clean the filter bed.

Continuous Backwashing Upflow Sand Filters

During operation of the continuous backwashing upflow filter, water is introduced through risers at the bottom of a deep sand bed. Water flows upward through the sand bed and over an overflow weir. Sand and trapped solids flow downward through the filter and are drawn into the suction of an airlift pipe in the center of the filter. As the sand travels up the airlift pipe, energy from the air scours the particles and separates the sand from filtered solids. At the top of the airlift pipe, the clean sand settles back onto the top of the filter and the solids are carried away into a reject line.

These filters have the advantage of having no moving parts other than the air compressor and requiring less energy and maintenance than traditionally backwashed filters. They are sometimes referred to by the trade name Dynasand.

Pulsed Bed Filters

Pulsed bed filters are shallow filters with an unstratified fine sand media. An air pulse disturbs the media and allows penetration of solids into media bed, allowing the entire filter bed to be used for removal of solids. The pulse is designed to expand the filter operation and reduce the number of backwash cycles, although the filter must still be periodically backwashed to remove the solids.

Traveling-Bridge Filters

Traveling-bridge filters consist of long shallow beds of granular media. Wastewater is applied to the top of the media and flows downward. Each cell is individually backwashed by a traveling-bridge while the other cells continue to operate. The bridge uses filtered water to backwash the filters and includes surface wash to breakup matted solids or clumps of solids.

Fuzzy Filters

The fuzzy filter uses a proprietary synthetic filter media that is highly porous. Water flows not only around the media but also through it, allowing much higher filtration rates. The media is held in place by a metal plate and flow is from the bottom of the bed upwards. The filter is backwashed by raising the plate and introducing a horizontal air stream from alternating sides causing the media to roll back and forth. The effluent is returned to the plant.

Discfilters

Discfilters are a series of parallel mounted disks used to support a cloth filter media. Water enters a central tube and flows out between the two layers of cloth in each disk. The disks rotate and are normally 60 to 70 percent submerged. The portion above the water is backwashed using spray nozzles.

Cloth Media Disk Filters

The cloth media disk filter is similar to the discfilter listed above. In this case the water flows from the outside of the partially submerged cloth disks and into a center pipe. Disks continue to rotate during backwash and water is sucked into the disc using suction heads.

Membranes

Membrane systems use a pressure head to drive water through a permeable membrane. Membrane filters are typically classified by their pore size which in turn determines the size of the particles they exclude. Microfiltration, ultrafiltration, nanofiltration, and reverse osmosis (RO) remove increasingly smaller particles. Microfiltration and ultrafiltration remove 3 to 6 logs of bacteria, 95 percent or more BOD, along with most particles (WEF, 2006). Nanofiltration removes nearly all particles including some viruses. RO removes all particles as well as most large dissolved constituents. The energy cost for applying the pressure head and the need to replace membranes make membrane filtration a more expensive technology. It can achieve very low concentrations of nutrients and other contaminants, however, and is common in water re-use projects.

Membranes can be configured a number of ways including hollow fiber, spiral wound, plate and frame, cartridge, or in pressure vessels. Membranes can foul from organics, biological activity, or metals in the wastewater. Typically the water must be pre-treated before using these membranes. Pretreatment could be conventional filters, cartridge filters, or larger membrane filters. Disinfection may also be required to prevent biological fouling.

Blue PROTM Process

The Blue PROTM process uses a continuous backwashing filter that is designed remove phosphorus. Filters can be run in series for even greater removal. The filter media (sand) is coated with a hydrous ferric oxide coating, which enhances phosphorus removal through adsorption. A ferric salt is added prior to the filter to aid in coagulation and to replace the ferric coating which is abraded from the sand. Water flows up through the filter while the sand travels down. An airlift tube at the bottom of the filter carries the sand upward.

Turbulence from the compressed air knocks accumulated iron and phosphorus along with any solids off the particle as it travels upward. The iron, phosphorus, and particles are wasted, while the clean sand is deposited on the top of the bed. The filters can be run biologically active to achieve denitrification.

The Blu-CAT process combines the Blu-Pro process with addition of advanced oxidants. Early pilot tests show that this process is capable of removing other emerging contaminants along with phosphorus and microorganisms (USEPA, 2008a).

Pressure Filters

Pressure filters are similar to conventional media filters except they are contained in closed containers and are filtered under pressure. The increased pressure creates a greater head loss and allows longer times between backwashes.

Design and Operating Principles

Filtration is mainly affected by the concentration and size distribution of particles entering the filter. Turbidity is often used as a surrogate for particle concentration. The concentration of particles will affect run-time in filters and will also affect the required surface area to achieve the desired filtration. The size distribution of the particles and its relevance to pore size of the granular or membrane filters will affect the removal mechanisms. Filtration rate is also an important design parameter. Too fast of a filtration rate can cause floc to break up and pass through the filter. The optimal filtration rate depends on floc strength, which in turn depends on the biological treatment processes prior to filtration (e.g., Higher SRTs lead to weaker flocs). The filtration rate, along with the loading rate will determine the area of the filter required. The higher the loading rate, the more frequent backwashes will be required and the greater the head loss across the filters. Typical filtration rates are 5 to 15 meters per hour for gravity filters and up to 20 meters per hour for pressure filters (WEF and ASCE, 1998).

Addition of polymers or other coagulant aids can greatly aid filtration. Typical doses for filter influent are 0.05 to 0.15 mg/L of organic polyelectrolyte (WEF and ASCE, 1998), although jar tests are conducted to determine the proper dose. Too low a dose can allow uncoagulated particles through the filter and too high a dose can lead to mudballs and filter clogging.

There are several ways the flow rate can be controlled in filters. Constant-rate fixed head filtration maintains a constant flow through the filter. This will lead to an increased head above the filter as the filter run progresses. In constant-rate variable head filtration the rate is kept the same and the filter is backwashed when the head reaches a certain value. In variable-rate filtration, the rate of filtration decreases throughout the filter run until it reaches a minimum value and is backwashed.

Variable-rate filtration is less common than constant-rate filtration.

Proper backwashing is also important to filter operation. Without proper backwashing there can be breakthrough of particles and turbidity. Lack of a proper backwash can also lead to accumulation of materials on the surface of the filter that can form mudballs and cracks, which can allow solids to pass through the filter. A surface wash or air scour may also be helpful to prevent accumulation of mudballs or grease. Surface wash or air scour is also helpful for traveling bridge filters. Without surface wash traveling bridge filters are limited to an influent TSS concentration of 40 to 50 mg/L (WEF and ASCE, 1998).

If membrane filters are used, fouling can be an important consideration. Cellulose acetate membranes can be damaged by biological activity. Disinfection is often used to prevent biological fouling of the membranes. Some membrane materials such as polyacramides, however, can be damaged by chlorine. This can be avoided by using an alternative disinfectant, a different membrane material, or by de-chlorination. Lowering the pH can help to prevent mineral fouling of nanofiltration or reverse osmosis membranes. Besides pre-treatment, chemical cleaning of the membranes may also be required periodically. Monitoring of effluent quality and pressure differential can be important to help identify membrane fouling or failure.

Ongoing Research and Emerging Technologies

The use of membranes as tertiary filtration is an area that has recently expanded. Research continues on various membrane configurations along with topics such as pre-treatment, membrane cleaning, and removal of emerging contaminants. Fuzzy filters are also an innovative technology that is beginning to be established in the wastewater community with several full scale projects. Other research has focused on enhancements to existing technology. For example, the Blue-Pro system combines continuous backwashing filters, a well-known technology, with a hydrous ferric oxide coating and ferric salt addition to remove phosphorus by adsorption as well as filtration.

Mathematical Modeling

8.1 The Need for Models

WWTPs are complex systems that depend on numerous biological, chemical, and physical processes to achieve effluent goals. Because of the complex behavior of the processes and the variability in wastewater characteristics, biological populations, and plant design, it is not always possible to predict how changing any one variable will affect the effluent quality. Plant designs that work for one influent wastewater and climate may not perform well in different conditions. Pilot scale or full scale trials can help to determine the effect of various parameters, but costs and time to cover all possibilities may be prohibitive. Therefore, models fill an important need by enabling simulation of a process and estimating the impact that changing parameters will have on the treatment effectiveness.

Models can be used for a number of purposes including the design of new WWTPs, the design of retrofits or upgrades to existing plants, determining how changes in operations may affect effluent concentrations of permitted contaminants, determining how plants will respond to changes in influent quality or flow, and for training operators. Not all models can achieve all of these purposes, so models should be selected with the desired use in mind. There is some disagreement in the literature in the use of the term model. Some references use the term to refer to sets of mathematical equations that characterize a process, other references use model to refer to the computer program used to solve these equations. This section will use the former and will use the term “simulator” to describe the computer program.

Overview of Available Models

Models are sets of equations, generally based on theory and grounded in empirical data that represent a wastewater treatment process. Each unit process is represented by its own model. Model equations for processes such as clarification and settling are well known and fairly simple. Modeling biological wastewater processes such as activated sludge, however, is much more complicated. The primary set of models for activated sludge processes has been compiled by the International Water Association (IWA). The first model was developed in 1986 and was called the activated sludge model (ASM). Later known as ASM1, this model was able to model the biological oxidation of carbon, nitrification, and de-nitrification.

Although the ASM model gained widespread use among both academia and industry, it had limitations. For example the model assumed constant temperature and pH, did not include EBPR, and the biological reactions did not depend on the carbon source. In order to improve the model, IWA developed four other ASM models; ASM2, ASM2d, ASM3, and ASM3 with BioP. ASM2 and ASM2d were intended to add EBPR. The ASM3 models were intended to deal with limitations such as the independence of the ASM1 model of temperature and carbon source. In addition, other models were developed to seek to improve upon the ASM model. The metabolic biological phosphorus model of the Delft University of Technology (TUDP) was developed to fully account for the metabolism occurring in PAOs during EBPR. Barker and Dold (1997) developed a model (B&D) to include different rates of growth depending on the carbon source.

When selecting models, the processes required and the range of normal operating parameters for the plant should be considered and compared to the available models. For example, if chemical phosphorus removal is to be used in a plant, the plant is limited to using either the ASM2 or ASM2d models. Each model also has a range of temperatures and pH over which it is valid.

Nutrient Removal for Small Communities and Decentralized Wastewater Treatment Systems

Approximately 25 percent of the U.S. population is served by onsite septic or decentralized systems. Onsite septic systems treat and dispose of effluent on the same property that produces the wastewater, whereas decentralized treatment refers to onsite or cluster systems that are used to treat and dispose of relatively small volumes of wastewater, generally from dwellings and businesses that are located relatively close together. In many cases, wastewater from several homes is pretreated onsite by individual septic tanks before being transported through alternative sewers to an offsite decentralized treatment unit that is relatively simple to operate and maintain.

The remaining 75 percent of the population is served by centralized wastewater treatment facilities, which collect and treat large volumes of wastewater. There is, in fact, a growing movement toward decentralized or clustered wastewater treatment systems to reduce cost, to provide groundwater recharge near the source, and for speed and ease in siting since they are generally located underground. The use of residential cluster development is gaining in popularity across the U.S. as a means to permanently protect open space, preserve agricultural land, and protect wildlife habitat (Mega et al., 1998). As part of these developments, wastewater systems such as community drainfields, irrigation systems, and package plants are being installed to reduce infrastructure investment and minimize adverse environmental impacts. Additional alternatives that include aerobic tanks, sand filters, and constructed wetlands can be used to reduce nutrient pollution; particularly in sensitive coastal areas or over sensitive, unconfined aquifers used for drinking water (Anderson and Gustafson, 1998).

Phosphorus Removal

Few phosphorus removal processes are well developed for onsite wastewater systems application (USEPA, 2008e). The controlled addition of chemicals such as aluminum, iron, and calcium compounds with subsequent flocculation and sedimentation has had only limited success because of inadequate operation and maintenance of mechanical equipment and excessive sludge production. Most notable successes have come with special filter materials that are naturally high in their concentration of the above chemicals, but their service lives are finite. Studies of high-iron sands and high-aluminum muds indicate that 50 to 95 percent of the phosphorus can be removed. However, the life of these systems has yet to be determined, after which the filter media will have to be removed and replaced. Use of supplemental iron powder mixed with natural sands is also being researched. Aside from specialized filter media, the most likely phosphorus-reduction systems are iron-rich intermittent sand filter (ISF) media and SBRs. These are discussed in more detail below.

Nitrogen Removal

Processes that remove 25 to 50 percent of total nitrogen include aerobic biological systems and media filters, especially recirculating filters (USEPA, 2008f). The vast majority of on-site and cluster nitrogen-removal systems employ nitrification and denitrification biological reactions. Most notable of these are recirculating sand filters (RSFs) with enhanced anoxic modifications, SBRs, and an array of aerobic nitrification processes combined with an anoxic/anaerobic process to perform denitrification. Some of the combinations are proprietary. A few recently developed highly instrumented systems that utilize membrane solids separation following biological nitrification and denitrification are capable of removing total nitrogen down to very low concentrations (i.e. 3 – 4 mg/L TN). Nitrogen removal systems generally are located last in the treatment train prior to subsurface wastewater infiltration system (SWIS) disposal or surface water disposal, in which case a disinfection step is typically required. Usually, the minimum total nitrogen standard that can be regularly met is about 10 mg/L. These technologies can be either above ground or below ground.

Nitrogen and Phosphorus Removal Technologies

Introduction

This section provides information on a number of different technologies that can reduce nitrogen and phosphorus levels. The actual technology selected will be site-specific and dependent on many factors including soil conditions, influent water quality, required effluent levels, disposal options, availability of land, cost, etc. In some cases, a combination of technologies may be necessary to effectively remove all the contaminants of concern. Small system owners and operators should work closely with their state onsite and decentralized program staff as well as engineers to ensure that the technologies selected will work effectively in combination to achieve the effluent goals.

Nutrient Removal Technologies

Fixed-film systems - Aerobic/anaerobic trickling filter package plant

Fixed-film systems (FFSs) are biological treatment processes that employ a medium such as rock, plastic, wood, or other natural or synthetic solid material that will support biomass on its surface and within its porous structure (USEPA, 2008c). Trickling filter FFSs are typically constructed as beds of media through which wastewater flows. Oxygen is normally provided by natural or forced ventilation. Commercial on-site systems use synthetic media and receive wastewater from overlying sprayheads for aerobic treatment and nitrification. Nitrified effluent returns to the anoxic zone to mix with either septic tank contents or incoming septic tank effluent for denitrification. A portion of the denitrified effluent is discharged for disposal or further treatment. Aerobic tanks are available in residential or small community sizes. Typical trickling filters systems currently available are capable of producing effluent BOD and TSS concentrations of 5 to 40 mg/L. Nitrogen removal typically varies from 0 to 35 percent although removal percentages as high as 65% have been demonstrated through USEPA's Environmental Technology Verification (ETV) program. Phosphorus removal is typically 10 to 15 percent.

Higher removal occurs at low loading rates in warm climates. Systems can be configured for single-pass use where the treated water is applied to the trickling filter once before being disposed of, or for multi-pass use where a portion of the treated water is cycled back to the septic tank and re-treated via a closed loop.

Multi-pass systems result in higher treatment quality and assist in removing Total Nitrogen (TN) levels by promoting nitrification in the aerobic media bed and denitrification in the anaerobic septic tank. Factors affecting performance include influent wastewater characteristics, hydraulic and organic loading, medium type, maintenance of optimal DO levels, and recirculation rates.

Sequencing batch reactor (SBR)

The SBR process is a sequential suspended growth (activated sludge) process in which all major steps occur in the same tank in sequential order (USEPA, 2008d). The SBR system is typically found in packaged configurations for onsite and small community or cluster applications. The major components of the package include the batch tank, aerator, mixer, decanter device, process control system (including timers), pumps, piping, and appurtenances. Aeration may be provided by diffused air or mechanical devices. SBRs are often sized to provide mixing as well and are operated by the process control timers.

Mechanical aerators have the added value of potential operation as mixers or aerators. The decanter is a critical element in the process. Several decanter configurations are available, including fixed and floating units. At least one commercial package employs a thermal processing step for the excess sludge produced and wasted during the "idle" step. The key to the SBR process is the control system, which consists of a combination of level sensors, timers, and microprocessors which can be configured to meet the needs of the system.

SBRs can be designed and operated to enhance removal of nitrogen, phosphorus, and ammonia, in addition to removing TSS and BOD. Package plant SBRs are suitable for areas with little land, stringent treatment requirements, and small wastewater flows such as RV parks or mobile homes, campgrounds, construction sites, rural schools, hotels, and other small applications. These systems are also useful for treating pharmaceutical, brewery, dairy, pulp and paper, and chemical wastes (USEPA, 2000d).

Intermittent sand filters (ISF)

ISF is used to describe a variety of packed-bed filters of sand or other granular materials available on the market (USEPA, 2008g). Sand filters provide advanced secondary treatment of settled wastewater or septic tank effluent. They consist of a lined (e.g., impervious PVC liner on sand bedding) excavation or structure filled with uniform washed sand that is placed over an underdrain system. The wastewater is directed onto the surface of the sand through a distribution network and allowed to percolate through the sand to the underdrain system. The underdrain system collects the filter effluent for further processing or discharge.

Sand filters are aerobic, fixed-film bioreactors. Bioslimes from the growth of microorganisms develop as films on the sand particle surfaces. The microorganisms in the slimes capture soluble and colloidal waste materials in the wastewater as it percolates over the sand surfaces. The captured materials are metabolized into new cell mass or degraded under aerobic conditions to carbon dioxide and water. Most biochemical treatment occurs within approximately 6 inches of the filter surface. Other treatment mechanisms that occur in sand filters include physical processes, such as straining and sedimentation, to remove suspended solids within the pores of the media. Most suspended solids are strained out at the filter surface.

Chemical adsorption can occur throughout the media bed. Adsorption sites in the media are usually limited, however. The capacity of the media to retain ions depends on the target constituent, the pH, and the mineralogy of the media. Phosphorous is one element of concern in wastewater that can be removed in this manner, but the number of available adsorption sites is limited by the characteristics of the media.

Sand filters can be used for a broad range of applications, including single-family residences, large commercial establishments, and small communities. Sand filters are frequently used to pretreat septic tank effluent prior to subsurface infiltration onsite where the soil has insufficient unsaturated depth above ground water or bedrock to achieve adequate treatment. They are also used to meet water quality requirements (with the possible exception of fecal coliform removal) before direct discharge to surface water. Sand filters are used primarily to treat domestic wastewater, but they have been used successfully in treatment trains to treat wastewaters high in organic materials such as those from restaurants and supermarkets. Single-pass ISF filters are most frequently used for smaller applications and sites where nitrogen removal is not required. However, they can be combined with anoxic processes to significantly increase nitrogen removal.

Recirculating sand filters (RSF)

Recirculating filters using sand, gravel, or other media provide advanced secondary treatment of settled wastewater or septic tank effluent (USEPA, 2008h). They consist of a lined (e.g., impervious PVC liner on sand bedding) excavation or structure filled with uniform washed sand that is placed over an underdrain system. The wastewater is directed onto the surface of the sand through a distribution network and allowed to percolate through the sand to the underdrain system. The underdrain system collects and recycles the filter effluent to the recirculation tank for further processing or discharge.

The basic components of recirculating filters include a recirculation/dosing tank, pump and controls, distribution network, filter bed with an underdrain system, and a return line. The return line or the underdrain must split the flow to recycle a portion of the filtrate to the recirculation/dosing tank. A small volume of wastewater and filtrate is dosed to the filter surface on a timed cycle 1 to 3 times per hour.

Recirculation ratios are typically between 3:1 and 5:1. In the recirculation tank, the returned aerobic filtrate mixes with the anaerobic septic tank effluent before being reapplied to the filter. RSFs can be used for a broad range of applications, including single-family residences, large commercial establishments, and small communities. They produce a high quality effluent with approximately 85 to 95 percent BOD and TSS removal. In addition, almost complete nitrification is achieved.

Denitrification also has been shown to occur in RSFs. Depending on modifications in design and operation, 50 percent or more of applied nitrogen can be removed (USEPA, 1999). To enhance this capability, they can be combined with a greater supply of biodegradable organic carbon, time, and mixing than is normally available from the conventional recirculation tank.

Natural Systems

The natural systems described here include constructed wetlands and floating aquatic plant treatment systems. Wetland systems are typically described in terms of the position of the water surface and/or the type of vegetation grown. Most natural wetlands are free water surface (FWS) systems where the water surface is exposed to the atmosphere; these include bogs (primary vegetation mosses), swamps (primary vegetation trees), and marshes (primary vegetation grasses and emergent macrophytes) (USEPA, 2000e). subsurface flow (SF) wetlands are specifically designed to treat or polish wastewater and are typically constructed as a bed or channel containing appropriate media.

Constructed wetlands treat wastewater by bacterial decomposition, settling, and filtering. As in tank designs, bacteria break down organic matter in the wastewater, aerobically, anoxically and anaerobically. Oxygen for aerobic decomposition is supplied by the plants growing in the wetland. Solids are filtered and finally settle out of the wastewater within the wetland. After about two weeks in the wetland, effluent is usually discharged by gravity to an unlined wetland bed. If these systems discharge effluent to surface ditches, they require a NPDES permit.

The submerged plant roots do provide substrate for microbial processes. However, the amount of oxygen that emergent macrophytes can transmit from the leaves to their roots is negligible compared to the oxygen demand of wastewater. Therefore subsurface flow wetlands are devoid of oxygen. The lack of oxygen in these subsurface flow systems means that ammonia oxidation via biological nitrification will not occur without the use of an additional unit process, such as a gravel trickling filter for nitrification of the wastewater ammonia. Vertical flow wetland beds are a modification of subsurface flow wetlands which contain gravel or coarse sand and are loaded intermittently at the top surface. Unlike ammonia oxidation, nitrate removal in a subsurface flow wetland can be rapid and effective because the anoxic conditions and carbon sources necessary to support the treatment reactions occur naturally in these systems.

FWS wetlands with long detention times can remove minor amounts of phosphorus through plant uptake, adsorption, complexation, and precipitation. However, removal via plant uptake is limited to phosphorus retained in plant litter that is buried by sediments before plant decomposition occurs (i.e. peat building process). Phosphorus removal is typically greater in the first year or two because of soil absorption and rapidly expanding vegetation but decreases when the system reaches equilibrium, and unburied plant litter releases phosphorus back into the water as it decomposes. Phosphorus removal is also possible with the use of an addition process, such as chemical addition and mixing prior to a final deep settling pond.

Aquatic systems using duckweed have been used for a number of years to treat wastewater for various purposes (WEF, 2001). Duckweed (*Lemna spp.*) are floating macrophytes. Duckweed fronds can double their mass in two days under ideal conditions of nutrient availability, sunlight, and temperature. Although duckweed can be found in most regions, the rate of growth is optimal at 20 to 30°C and they grow best in a pH range of 3.5 to 8.5.

Duckweed can grow about six months per year in most U.S. climates. High levels of BOD and TSS removal have been observed from duckweed systems. To achieve secondary treatment most duckweed systems are coupled with either facultative or aerated ponds. Nitrogen is removed by plant uptake and harvesting, by denitrification, or a combination of the two. Typically less than 1 mg/L of phosphorus can be removed by plant uptake and harvest. If significant phosphorus removal is required, chemical precipitation with alum, ferric chloride, or other chemicals used in a separate treatment step is necessary. The major disadvantage of duckweed systems is the large amount of biomass produced by the rapidly growing plants, which creates a solids handling requirement similar to handling sludge at an aerobic wastewater treatment facility.

Proprietary Filters/Improved and Emerging Technologies

A number of companies have developed proprietary nitrogen and phosphorus removal technologies that can be used at centralized wastewater treatment facilities as well as at onsite, decentralized systems. This section provides a general description of some of these technologies without mentioning specific trade names.

Sustainable Nutrient Recovery

While the U.S. is primarily addressing nutrient removal concerns through development of WQSs and treatment at centralized wastewater facilities, a number of European countries including Switzerland, Sweden, and the Netherlands are conducting research on innovative sustainable nutrient recovery systems. The concept behind these new technologies is to separate and treat toilet waste before it leaves the home or building and mixes with the larger waste stream to be carried to WWTPs.

Recent studies have shown that about 80 percent of the nitrogen and 50 percent of the phosphorus in wastewater are derived from urine although urine makes up only 1 percent of the volume of wastewater (Larsen and Leinert, 2007). Separating the urine from wastewater could offer various advantages: WWTPs could be built on a smaller scale, water bodies will be better protected from nitrogen and phosphorus pollution, nutrients could be recycled for agricultural use, and various constituents of concern including hormones and pharmaceutical compounds could be removed before being mixed with wastewater and released to the environment. A major benefit would be reduced energy consumption at WWTPs as a result of reduced treatment requirements for nitrogen. Also, separating 50 to 60 percent of urine could reduce in-plant nitrogen gas discharges and result in fewer impurities in methane captured from sludge digestion.

Organizations such as the Swiss Federal Institute of Aquatic Science and Technology (Eawag) are currently experimenting with the development and application of “NoMix technology” to separate urine from solid waste at the toilet bowl. While similar in size and shape to current toilets, this new technology has two waste pipes – a small front one that collects and diverts urine into a storage tank, and a larger rear waste pipe that operates like a standard toilet. The first of these toilets were installed in two “eco-villages” in Sweden in 1994 and since then have spread to other locations throughout the country and to Denmark, the Netherlands, and Switzerland. The concept is now taking hold in Austria and Germany. While the pollutant-free urine, or “urevit,” can be spray-applied directly onto agricultural fields; in the Netherlands, a company called Grontmij trucks stored urine to a special treatment plant where the phosphate is precipitated out as a mineral called struvite and used as a fertilizer.

Novaquatis, a branch of Eawag is experimenting with extracting nitrogen and potassium from urine that can be sprayed directly onto crops. Eawag is also experimenting with a pilot decentralized basement sewage plant where domestic wastewater is treated in a MBR so it can be reused for flushing the toilets or watering the garden and the sewage sludge is composted. While still experimental, some of these technologies may have practical future applications if widely applicable low-cost solutions can be found for urine transport, or stable and cost-effective technologies can be developed for decentralized treatment.

While studies of consumer attitudes and acceptance appear to be positive, technological improvements are still needed to prevent clogging in pipes, to identify best treatment options that can be applied in practice; and to identify how and where to convert urine to fertilizer.

Sustainability concerns are also driving the wastewater treatment industry to start looking at sludge as a renewable resource. Historically, agricultural use has been the traditional approach for disposal of municipal sludge due to its high nutrient content for fertilizing crops, and its low cost approach. As scientific advances detect smaller and smaller quantities of contaminants (i.e., heavy metals, pathogenic microorganisms, pharmaceuticals, and personal care products), the public, farming organizations, and the food industry are raising concerns about continuing this practice.

As noted above, researchers are discovering that valuable products can be generated from sewage treatment byproducts such as energy extracted from anaerobic digestion, construction materials such as bricks, and nutrients such as phosphorus that can be extracted from sludge and used as fertilizer.

In February 2008, the non-profit Global Water Research Coalition, an international water research alliance formed by 12 world-leading research organizations, released a report titled, *State of Science Report: Energy and Resource Recovery from Sludge* (Kalogo and Monteith, 2008). The report focuses on:

- The international situation of energy and resource recovery from sludge
- How the use of different sludge treatment processes affects the possibility of recovering energy and/or materials from the residual sludge
- The influence of market and regulatory drivers on the fate of the sludge end-product
- The feasibility of energy and resource recovery from sludge
- The social, economic, and environmental performance (triple bottom line or TBL assessment) of current alternatives technologies

Four market drivers are identified and discussed including:

- Sustainability and environmental concerns, such as the threat of soil pollution, global warming and resource depletion
- Rising energy costs and the need of more electricity and heat to operate the plants
- Requirements for high quality of resources for industrial applications, such as calcium phosphate for the phosphate industry
- Regulation as a factor stimulating the development of new technologies

In the report, energy recovery technologies are classified into sludge-to-biogas processes, sludge-to-syngas processes, sludge-to-oil processes, and sludge-to-liquid processes. The technologies available for resource recovery discussed in the report include those to recover phosphorus, building materials, nitrogen, and volatile acids. The report, which covers both established as well as emerging technologies, will be used as the basis for development of the coalition's future strategic research plan on energy and recovery from sludge. As a technical resource, it provides a valuable overview of sludge disposal practices in various countries such as the U.S., the Netherlands, the United Kingdom, Germany, Sweden, Japan, and China; and presents a number of treatment processes for resource recovery.

Other groups have looked at recovering phosphorus from the supernatant from anaerobic digestion. Several different processes have been proposed that rely on precipitation of the phosphorus as either struvite or calcium phosphate. Work is underway on projects in Italy, Germany, the Netherlands, and Canada (SCOPE, 2004).

Co-Removal of Emerging Contaminants

This section provides a brief background on emerging contaminants and key findings from studies on the co-removal of emerging contaminants by nutrient removal technologies.

Background on Emerging Contaminants

The term “emerging contaminants” refers broadly to those synthetic or naturally occurring chemicals, or to any microbiological organisms, that have not been commonly monitored in the environment but which are of increasing concern because of their known or suspected adverse ecological or human health effects. Emerging contaminants can fall into a wide range of groups defined by their effects, uses, or by their key chemical or microbiological characteristics. Two groups of emerging contaminants that are of particular interest and concern at present are endocrine disrupting chemicals (EDCs) and pharmaceutical and personal care products (PPCPs). These compounds are found in the environment, often as a result of human activities.

EDCs may interfere with the endocrine systems by damaging hormone-producing tissues, changing the processes by which hormones are made or metabolized, or mimicking hormones. In addition to natural and synthetic forms of human hormones that are released into the environment, there are a multitude of synthetic organic compounds that are able to disrupt the endocrine system. Public concern about EDCs in the environment has been rapidly increasing since the 1990s when researchers reported unusual sexual characteristics in wildlife. A report by the USGS, found that fish in many streams had atypical ratios of male and female sex hormones (Goodbred et al., 1997). In England, researchers found that male trout kept in cages near WWTP outfalls were developing eggs on their testes and had increased levels of the protein that is responsible for egg production (vitellogenin) (Sumpter, 1995; Kaiser, 1996). Follow-up laboratory studies showed that synthetic forms of estrogen (17 α -ethynylestradiol (EE2)) could increase vitellogenin production in fish at levels as low as 1-10 ng/L, with positive responses seen down to the 0.1-0.5 ng/L level (Purdom et al., 1994).

Human estrogens have the ability to alter sexual characteristics of aquatic species at trace concentrations as low as 1 ng/L (Purdom et al., 1994). WWTP effluents have been identified as a primary source for EDCs in the environment, with the bulk of their endocrine disrupting activity resulting from human estrogen compounds (Desbrow et al., 1998; Snyder et al., 2001). The synthetic estrogen, EE2, and the natural estrogens, estrone (E1) and 17 β -estradiol (E2), are the greatest contributors to endocrine disrupting activity in WWTP effluent (Johnson et al., 2001) with EE2 showing the greatest recalcitrance in WWTPs (Joss et al., 2004). Influent concentrations range from below detection to 70 ng/L for EE2, 670 ng/L for E1 and 150 ng/L for E2 (Vethaak et al., 2005; Clara et al., 2005b). Other EDCs include tributyl tin, which was previously used in paints to prevent marine organisms from sticking to ships, nonylphenol (a surfactant), and bisphenol A (plasticizer and preservative).

PPCPs encompass a wide variety of products that are used by individuals for personal health or cosmetic reasons, and also include certain agricultural and veterinary medicine products. PPCPs comprise a diverse collection of thousands of chemical substances, including prescription and over-the counter therapeutic drugs, veterinary drugs, fragrances, sun-screen products, vitamins, and cosmetics. Many of these products, notably the pharmaceuticals for human or animal use, are specifically designed to be biologically active, and some PPCPs may also fall into the category of EDCs described previously.

Estrogens of Concern

Name	Chemical Structure	Name	Chemical Structure
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E1	Estrone	C18H22O2
E2	17 β -estradiol	C18H24O2
E3	Estriol	C18H24O3
EE2	17 α -ethynylestradiol	C20H24O2

Currently, municipal sewage treatment plants are engineered to remove conventional pollutants such as solids and biodegradable organic material but are not specifically designed for PPCP removal or for other unregulated contaminants. Wastewater treatment commonly consists of primary settling followed by biological treatment, secondary settling, and disinfection.

This treatment can remove more than 90 percent of many of the most commonly known or suspected EDCs found in wastewater influent; however, low concentrations of some suspected EDCs may remain in the wastewater treatment sludge or effluent (WERF, 2005). As discussed in the next section, studies have shown enhanced nutrient removal technologies to be effective in removing low concentrations of some emerging contaminants.

Removal of Emerging Contaminants by Nutrient Removal Technologies

Several studies have examined the effectiveness of current wastewater treatment technologies in the removal of emerging contaminants. Some of these studies are discussed below and their major findings are organized under three subsections: role of activated sludge SRT in removal efficiency, role of nitrifying bacteria in biodegradation, and use of RO to improve removal efficiencies. Details regarding the study design, such as evaluated treatments and contaminants, and a summary of major study findings are provided at the end of this section.

The significant findings are also presented as follows:

- Removal efficiencies were enhanced for several investigated contaminants at longer SRTs, with critical SRTs for some beyond which removal rates did not improve.
- Longer SRTs allow for the establishment of slower growing bacteria (e.g., nitrifying bacteria in activated sludge), which in turn provide a more diverse community of microorganisms with broader physiological capabilities.
- Nitrifying bacteria may play a key role in biodegradation but the role of heterotrophic bacteria may also play a significant role.
- Reverse osmosis has been found to effectively remove PPCPs below detection limits including those that were not consistently removed at longer SRTs.

One caveat regarding studies on emerging contaminants is that their concentrations in wastewater influent are often quite low (e.g., concentrations of ng/L to µg/L range) and may be close to method detection limits. Therefore, small variations between measured influent and effluent concentrations may show large variations in apparent removal efficiencies, possibly even producing negative calculated removals.

Role of Solids Retention Time in Removal Efficiency

The focus of several studies has been the relationship of the SRT to the removal of emerging contaminants. In particular, many investigated whether longer SRTs would result in increased removal efficiencies for estrogens and other categories of PPCPs. Longer activated sludge SRTs allow for the establishment of slower growing bacteria (e.g., nitrifying bacteria in activated sludge), which in turn provide a more diverse community of microorganisms with broader physiological capabilities.

Clara et al. (2005a), Kreuzinger et al. (2004), and Oppenheimer et al. (2007) observed enhanced removal with increasing SRTs for most of the EDCs and pharmaceuticals tested and found no significant differences in removal performances between conventional activated sludge systems and MBR when operated at similar SRTs. This is likely due to the molecular weight of the study compounds, which was smaller than the molecular weight cut-off of the ultrafiltration membranes in the MBR.

Researchers have observed similar findings for natural estrogens with higher removal percentages at longer SRTs. Effluent concentrations for three natural estrogens were measured near their detection limits at SRTs 10° C higher than 10 days, with their critical SRTs 10° C estimated between 5 and 10 days (Clara et al., 2005a).

High removal rates of > 90 percent were also observed by Joss et al. (2004) in a study in which they evaluated the removal of E1, E2, and EE2 under aerobic and anaerobic conditions in WWTPs designed for nutrient removal. Joss et al. (2004) also reported that the maximum efficiency is dependent on redox conditions, with the highest removal rate occurring during the reduction of E1 to E2 under aerobic conditions. Clara et al. (2005a) cited examples where conflicting results were obtained for EE2.

Ternes et al. (1999) found no significant elimination of this compound during batch experiments; however, Baronti et al. (2000) and Joss et al. (2004) report greater than 85 percent removal in full-scale WWTPs. For the pharmaceuticals ibuprofen and bezafibrate, Clara et al. (2005a) reported more than 95 percent

removal during treatment and calculated the critical value for SRT_{10° C} at 5 days for ibuprofen and about 10 days for bezafibrate. Analogous removal results were obtained in several other studies (Stumpf et al., 1998; Buser et al., 1999; Zwiener et al., 2001, as cited in Clara et al., 2005a; Oppenheimer et al., 2007). Clara et al. (2005b) noted no or slight removal of these two pharmaceuticals and two musk fragrances (tonalide and galaxolide) at a WWTP with a low SRT of 1 to 2 days.

Clara et al. (2005a, 2005b) also found that the pharmaceutical carbamazepine was not removed during wastewater treatment. In addition, these studies found contradictory results for diclofenac (e.g., removal rates ranged from no removal to > 70 percent at SRTs of > 10 days (Clara et al., 2005b)). Clara et al. (2005a) also cited several examples where conflicting results were obtained for diclofenac. No significant removal was reported by Buser et al. (1999) and Heberer (2002a); whereas, Ternes et al. (1998) observed elimination rates of up to 70 percent.

Clara et al. (2005a, 2005b) concluded that the removal potential for conventional WWTPs and MBRs depends on the SRT. They further concluded that high removal rates can be achieved at SRTs_{10° C} of more than 10 days. These parameters correspond to the design criteria for nitrogen removal in the German Association for Water, Wastewater and Waste (ATV-DVWK, 2000) and the urban wastewater directive of the European Community (91/271/EEC) for WWTPs in sensitive areas. In its 2005, technical brief, "Endocrine Disrupting Compounds and Implications for Wastewater Treatment," WERF summarized information from several studies that examined the effectiveness of current wastewater treatment technologies in the removal of EDCs.

The classes of EDCs included:

steroids/sterols (naturally occurring, synthetic, and phytoestrogens), organohalides, metals/organometals, alkyl phenols, polycyclic aromatic hydrocarbons (PAHs)/crude oil, and plasticizers.

Although the WERF 2005 technical brief states that in general, EDC treatment effectiveness is improved with increased SRT, it does not provide the specific SRTs that are associated with the cited removal rates.

Oppenheimer et al. (2007) examined the relationship of SRT to treatment removal efficiencies for 20 PPCPs that are commonly found in the influent of U.S. treatment facilities. Many of the studies already discussed here have been conducted primarily in Europe, were conducted at small-scale WWTPs and bench/pilot plants under controlled conditions, and focused on estrogens and prescription pharmaceuticals rather than PPCPs. The Oppenheimer et al. (2007) study also noted trends regarding the effect of HRT and pure oxygen systems compared to conventional aeration systems on PPCP removal.

Oppenheimer et al. (2007) defined a minimum critical SRT as the minimum time needed to consistently demonstrate greater than 80 percent removal. The results of the study showed that this critical SRT was compound dependent but that the majority of the 20 PPCPs were consistently removed in those treatment plants operating at SRTs of 5 to 15 days. Specifically, 9 of 12 frequently occurring PPCPs were effectively removed through secondary treatment (e.g., ibuprofen).

Conversely, six compounds that are routinely detected in influent (i.e., detected in at least 20 percent of the influent samples) were not well removed by secondary treatment (BHA, DEET, musk ketone, triclosan, benzophenone, galaxolide).

The results for galaxolide conflicted with those reported by Clara et al. (2005b) who generally found high removal rates with SRTs > 10 days and Kreuzinger et al. (2004) who reported removal at SRT between 25 to 40 days. Oppenheimer et al. (2007) found that some compounds such as octylphenol, tri-(chloroethyl) phosphate, and triphenylphosphate were not well removed by secondary treatment; however, these were seldom detected in the influent samples. Based on these results, Oppenheimer et al. (2007) concluded that secondary treatment provides an "effective first barrier" for the 20 PPCPs in the study.

Oppenheimer et al. (2007) also noted trends regarding the effect of HRT and pure oxygen systems compared to conventional aeration systems on PPCP removal but determined that insufficient data existed to make any definitive conclusions. When the PPCP removal performance of a high-purity oxygenated activated sludge plant was compared to a conventional aeration system, the pure oxygen system showed higher removal rates although its SRT was shorter than the conventional aeration plant (i.e., 1 day versus 3 days). In addition, different HRTs operating at similar SRTs had similar removal rates, and therefore suggested that HRT does not significantly affect removal effectiveness in the investigated PPCPs.

Role of Nitrifying Bacteria in Biodegradation

As discussed above, longer SRTs allow for the establishment of slow-growing nitrifying bacteria (i.e., ammonia oxidizing bacteria and nitrite-oxidizing bacteria). Several studies evaluated whether nitrifying bacteria improve the biodegradation of certain emerging contaminants. Major findings from some of these studies are discussed in this section.

The WERF (2005) technical brief indicated that secondary biological treatment that includes nitrification, nutrient removal, and disinfection may remove more than 90 percent of certain steroids, and >95 percent of alkyl phenols; whereas, secondary biological treatment without nitrification and disinfection may decrease removal of these by more than 15 percent. Batt et al. (2006) investigated the role of nitrifying bacteria in activated sludge in the biodegradation of two pharmaceuticals, iopromide and trimethoprim.

The biodegradation of these compounds was conducted in two lab-scale bioreactors using biomass from a stage-2 activated sludge WWTP (operated at an SRT of 49 days). In one of the bioreactors, nitrification was not inhibited (Batch-1 reactor); in the other, nitrification was inhibited with allylthiourea (Batch-2 reactor). Monitoring was also conducted in the WWTP and compared to results obtained from the batch reactors. Both reactors exhibited high removal rates for iopromide; however for trimethoprim, Batch-1 showed a high removal rate of 70 percent, contrasted to the Batch-2 reactor removal rate of approximately 25 percent with nitrification inhibited. Removal rates within the treatment plant, however, were consistent for both pharmaceuticals, showing significantly higher removal rate after nitrification (approx. 60 percent for iopromide and 50 percent for trimethoprim) compared to activated sludge treatment only (<1 percent for both).

Based on these results, Batt et al. (2006) concluded that nitrifying bacteria have a key role in the biodegradation of pharmaceuticals in WWTP that are operated at higher SRTs. This conclusion is supported by Martinen et al. (2003), who investigated the fate of phthalates in a WWTP with nitrogen removal and observed that about one third of the removal occurred in the nitrification/denitrification treatment phase.

Studies by Yi and Harper (2007), Khunjar et al. (2007), and others have focused on the mechanisms of estrogen removal during nitrification. Possible mechanisms include sorption of estrogens to solids and biotransformation within the treatment facility, especially in the presence of nitrifying activated sludges (Khunjar et al., 2007).

Ammonia oxidizing bacteria have monooxygenase enzymes for ammonia oxidation and these enzymes have been shown previously to be nonspecific and able to accomplish cometabolic degradation of recalcitrant organics.

Cometabolic degradation is a reasonable hypothesis for estrogen degradation because this compound is present at low ng/L concentrations that are below those expected to support microbial growth on that compound alone. One goal of the Yi and Harper (2007) study was to establish whether biotransformation of EE2 is due to cometabolic activity. They conducted batch experiments using enriched cultures of autotrophic ammonia oxidizers. Their study and others (Vader et al., 2000, Shi et al., 2004, as reported in Yi and Harper, 2007) showed a strong relationship between nitrification and EE2 removal in enriched nitrifying cultures.

Based on batch tests with and without a nitrifying bacteria inhibitor, they concluded that EE2 biotransformation can be cometabolically mediated in bioreactors that are enriched for autotrophic nitrifiers. However, Yi and Harper (2007) noted that the heterotrophic microorganisms, if present in activated sludge processes, may also be responsible for some micropollutant biotransformations. Further work is needed in this area as these tests did not identify the EE2 degradation product to confirm cometabolic degradation and the role of heterotrophs was not accounted for in some tests.

The focus of a Khunjar et al. (2007) study was to identify the role of ammonia oxidizing bacteria compared to heterotrophic bacteria in the biotransformation of EE2. They used pure cultures of ammonia oxidizing *Nitrosomonas europaea* and heterotrophic cultures that were enriched with monooxygenase and dioxygenase enzyme systems. Nitrifying activated sludge mixed liquors were taken from two WWTPs to seed the cultures. EE2 concentrations were 10-15 µg/L. The results of their study showed significant sorption of EE2 to the predominantly heterotrophic culture but none to the *N. europaea* culture. In addition, biotransformation of EE2 was significant in the *N. europaea* culture. They observed three major EE2 metabolites at different phases of *N. europaea* culture growth that suggest differential action on each byproduct by the nitrifying bacteria; however, additional work is needed to identify these byproducts. The authors also noted that additional research is needed with continuous flow cultivated *N. europaea* to determine whether these metabolites are likely to be present in nitrifying activated sludge. Also, *N. europaea* was not significantly inhibited at EE2 concentrations at or below 10 µg EE2/L, suggesting that ammonia oxidation may not be significantly impacted by concentrations of EE2 that may be typical of those found in the environment.

Use of Reverse Osmosis to Improve Removal Efficiencies

Several studies describe the effectiveness of RO in the removal of PPCP and EDCs from secondary wastewater effluent. Braghetta et al. (2002) calculated the removals rates that could be achieved with a RO step following tertiary treatment for 17 PPCPs. They estimated removals to be > 90 percent for most of the selected compounds. Lower removal rates were estimated for diclofenac (55.2 to 62 percent), ketoprofen (64.3 percent), and paraxanthine (73.7 percent).

As previously discussed, the WERF (2005) technical brief evaluated RO removal rates for several compounds. Specifically, the WERF brief cites numerous studies in which RO achieved removal rates of 90 percent or better for naturally occurring and synthetic steroids, organohalides, metals/organometals, and alkyl phenols. In addition, Oppenheimer et al. (2007) found that RO was effective in removing all 20 investigated PPCPs below the detection limit including those that were not consistently removed at SRTs of 30 days (i.e., galaxolide) using conventional activated sludge treatment or media filtration. Similar

**TITLE 40--PROTECTION OF ENVIRONMENT CHAPTER I--ENVIRONMENTAL
PROTECTION AGENCY PART 403--GENERAL PRETREATMENT REGULATIONS
FOR EXISTING AND NEW SOURCES OF POLLUTION**

33 U.S.C. 1251 et seq.

§ 403.1 Purpose and applicability.

(a) This part implements sections 204(b)(1)(C), 208(b)(2) (C)(iii), 301(b)(1)(A)(ii), 301(b)(2) (A)(ii), 301(h)(5) and 301(i)(2), 304 (e) and (g), 307, 308, 309, 402(b), 405, and 501(a) of the Federal Water Pollution Control Act as amended by the Clean Water Act of 1977 (Pub. L. 95-217) or "The Act". It establishes responsibilities of Federal, State, and local government, industry and the public to implement National Pretreatment Standards to control pollutants which pass through or interfere with treatment processes in Publicly Owned Treatment Works (POTWs) or which may contaminate sewage sludge.

(b) This regulation applies:

(1) To pollutants from non-domestic sources covered by Pretreatment Standards which are indirectly discharged into or transported by truck or rail or otherwise introduced into POTWs as defined below in § 403.3;

(2) To POTWs which receive wastewater from sources subject to National Pretreatment Standards;

(3) To States which have or are applying for National Pollutant Discharge Elimination System (NPDES) programs approved in accordance with section 402 of the Act; and

(4) To any new or existing source subject to Pretreatment Standards. National Pretreatment Standards do not apply to sources which Discharge to a sewer which is not connected to a POTW Treatment Plant.

(c) [Removed. See 60 FR 33932, June 29, 1995.]

Source

[46 FR 9439, Jan. 28, 1981, as amended at 48 FR 2776, Jan. 21, 1983; 60 FR 33932, June 29, 1995]

§ 403.2 Objectives of general pretreatment regulations.

By establishing the responsibilities of government and industry to implement National Pretreatment Standards this regulation fulfills three objectives:

(a) To prevent the introduction of pollutants into POTWs which will interfere with the operation of a POTW, including interference with its use or disposal of municipal sludge;

(b) To prevent the introduction of pollutants into POTWs which will pass through the treatment works or otherwise be incompatible with such works; and

(c) To improve opportunities to recycle and reclaim municipal and industrial wastewaters and sludges.

Source

46 FR 9439, Jan. 28, 1981.

§ 403.3 Definitions.

For the purposes of this part:

(a) Except as discussed below, the general definitions, abbreviations, and methods of analysis set forth in 40 CFR part 401 shall apply to this regulation.

(b) The term Act means Federal Water Pollution Control Act, also known as the Clean Water Act, as amended, 33 U.S.C. 1251, et seq.

(c) The term Approval Authority means the Director in an NPDES State with an approved State pretreatment program and the appropriate Regional Administrator in a non-NPDES State or NPDES State without an approved State pretreatment program.

(d) The term Approved POTW Pretreatment Program or Program or POTW Pretreatment Program means a program administered by a POTW that meets the criteria established in this

regulation (§§ 403.8 and 403.9) and which has been approved by a Regional Administrator or State Director in accordance with § 403.11 of this regulation.

(e) The term Director means the chief administrative officer of a State or Interstate water pollution control agency with an NPDES permit program approved pursuant to section 402(b) of the Act and an approved State pretreatment program.

(f) The term Water Management Division Director means one of the Directors of the Water Management Divisions within the Regional offices of the Environmental Protection Agency or this person's delegated representative.

(g) The term Indirect Discharge or Discharge means the introduction of pollutants into a POTW from any non-domestic source regulated under section 307(b), (c) or (d) of the Act.

(h) The term Industrial User or User means a source of Indirect Discharge.

(i) The term Interference means a Discharge which, alone or in conjunction with a discharge or discharges from other sources, both:

(1) Inhibits or disrupts the POTW, its treatment processes or operations, or its sludge processes, use or disposal; and

(2) Therefore is a cause of a violation of any requirement of the POTW's NPDES permit (including an increase in the magnitude or duration of a violation) or of the prevention of sewage sludge use or disposal in compliance with the following statutory provisions and regulations or permits issued there under (or more stringent State or local regulations): Section 405 of the Clean Water Act, the Solid Waste Disposal Act (SWDA) (including title II, more commonly referred to as the Resource Conservation and Recovery Act (RCRA), and including State regulations contained in any State sludge management plan prepared pursuant to subtitle D of the SWDA), the Clean Air Act, the Toxic Substances Control Act, and the Marine Protection, Research and Sanctuaries Act.

(j) The term National Pretreatment Standard, Pretreatment Standard, or Standard means any regulation containing pollutant discharge limits promulgated by the EPA in accordance with section 307 (b) and (c) of the Act, which applies to Industrial Users. This term includes prohibitive discharge limits established pursuant to § 403.5.

(k)(1) The term New Source means any building, structure, facility or installation from which there is or may be a Discharge of pollutants, the construction of which commenced after the publication of proposed Pretreatment Standards under section 307(c) of the Act which will be applicable to such source if such Standards are thereafter promulgated in accordance with that section, provided that:

(i) The building, structure, facility or installation is constructed at a site at which no other source is located; or

(ii) The building, structure, facility or installation totally replaces the process or production equipment that causes the discharge of pollutants at an existing source; or

(iii) The production or wastewater generating processes of the building, structure, facility or installation are substantially independent of an existing source at the same site. In determining whether these are substantially independent, factors such as the extent to which the new facility is integrated with the existing plant, and the extent to which the new facility is engaged in the same general type of activity as the existing source should be considered.

(2) Construction on a site at which an existing source is located results in a modification rather than a new source if the construction does not create a new building, structure, facility or installation meeting the criteria of paragraphs (k)(1)(ii), or (k)(1)(iii) of this section but otherwise alters, replaces, or adds to existing process or production equipment.

(3) Construction of a new source as defined under this paragraph has commenced if the owner or operator has:

(i) Begun, or caused to begin as part of a continuous onsite construction program:

(A) Any placement, assembly, or installation of facilities or equipment; or

(B) Significant site preparation work including clearing, excavation, or removal of existing buildings, structures, or facilities which is necessary for the placement, assembly, or installation of new source facilities or equipment; or

(ii) Entered into a binding contractual obligation for the purchase of facilities or equipment which are intended to be used in its operation within a reasonable time. Options to purchase or contracts which can be terminated or modified without substantial loss, and contracts for feasibility, engineering, and design studies do not constitute a contractual obligation under this paragraph.

(l) The terms NPDES Permit or Permit means a permit issued to a POTW pursuant to section 402 of the Act.

(m) The term NPDES State means a State (as defined in 40 CFR 122.2) or Interstate water pollution control agency with an NPDES permit program approved pursuant to section 402(b) of the Act.

(n) The term Pass Through means a Discharge which exits the POTW into waters of the United States in quantities or concentrations which, alone or in conjunction with a discharge or discharges from other sources, is a cause of a violation of any requirement of the POTW's NPDES permit (including an increase in the magnitude or duration of a violation).

(o) The term Publicly Owned Treatment Works or POTW means a treatment works as defined by section 212 of the Act, which is owned by a State or municipality (as defined by section 502(4) of the Act). This definition includes any devices and systems used in the storage, treatment, recycling and reclamation of municipal sewage or industrial wastes of a liquid nature. It also includes sewers, pipes and other conveyances only if they convey wastewater to a POTW Treatment Plant. The term also means the municipality as defined in section 502(4) of the Act, which has jurisdiction over the Indirect Discharges to and the discharges from such a treatment works.

(p) The term POTW Treatment Plant means that portion of the POTW which is designed to provide treatment (including recycling and reclamation) of municipal sewage and industrial waste.

(q) The term Pretreatment means the reduction of the amount of pollutants, the elimination of pollutants, or the alteration of the nature of pollutant properties in wastewater prior to or in lieu of discharging or otherwise introducing such pollutants into a POTW. The reduction or alteration may be obtained by physical, chemical or biological processes, process changes or by other means, except as prohibited by § 403.6(d). Appropriate pretreatment technology includes control equipment, such as equalization tanks or facilities, for protection against surges or slug loadings that might interfere with or otherwise be incompatible with the POTW. However, where wastewater from a regulated process is mixed in an equalization facility with unregulated wastewater or with wastewater from another regulated process, the effluent from the equalization facility must meet an adjusted pretreatment limit calculated in accordance with § 403.6(e).

(r) The term Pretreatment requirements means any substantive or procedural requirement related to Pretreatment, other than a National Pretreatment Standard, imposed on an Industrial User.

(s) The term Regional Administrator means the appropriate EPA Regional Administrator.

(t) Significant Industrial User. (1) Except as provided in paragraph (t)(2) of this section, the term Significant Industrial User means:

(i) All industrial users subject to Categorical Pretreatment Standards under 40 CFR 403.6 and 40 CFR chapter I, subchapter N; and

(ii) Any other industrial user that: discharges an average of 25,000 gallons per day or more of process wastewater to the POTW (excluding sanitary, noncontact cooling and boiler blowdown wastewater); contributes a process wastestream which makes up 5 percent or more of the average dry weather hydraulic or organic capacity of the POTW treatment plant; or is designated as such by the Control Authority as defined in 40 CFR 403.12(a) on the basis that

the industrial user has a reasonable potential for adversely affecting the POTW's operation or for violating any pretreatment standard or requirement (in accordance with 40 CFR 403.8(f)(6)).

(2) Upon a finding that an industrial user meeting the criteria in paragraph (t)(1)(ii) of this section has no reasonable potential for adversely affecting the POTW's operation or for violating any pretreatment standard or requirement, the Control Authority (as defined in 40 CFR 403.12(a)) may at any time, on its own initiative or in response to a petition received from an industrial user or POTW, and in accordance with 40 CFR 403.8(f)(6), determine that such industrial user is not a significant industrial user.

(u) The term Submission means:

(1) A request by a POTW for approval of a Pretreatment Program to the EPA or a Director;

(2) A request by a POTW to the EPA or a Director for authority to revise the discharge limits in categorical Pretreatment Standards to reflect POTW pollutant removals; or

(3) A request to the EPA by an NPDES State for approval of its State pretreatment program.

Source

[46 FR 9439, Jan. 28, 1981, as amended at 49 FR 5132, Feb. 10, 1984; 49 FR 28059, July 10, 1984; 51 FR 20430, June 4, 1986; 51 FR 23760, July 1, 1986; 52 FR 1600, Jan. 14, 1987; 53 FR 40610, Oct. 17, 1988; 55 FR 30129, July 24, 1990]

§ 403.4 State or local law.

Nothing in this regulation is intended to affect any Pretreatment Requirements, including any standards or prohibitions, established by State or local law as long as the State or local requirements are not less stringent than any set forth in National Pretreatment Standards, or any other requirements or prohibitions established under the Act or this regulation. States with an NPDES permit program approved in accordance with section 402 (b) and (c) of the Act, or States requesting NPDES programs, are responsible for developing a State pretreatment program in accordance with § 403.10 of this regulation.

Source

46 FR 9439, Jan. 28, 1981.

§ 403.5 National pretreatment standards: Prohibited discharges.

(a)(1) General prohibitions. A User may not introduce into a POTW any pollutant(s) which cause Pass Through or Interference. These general prohibitions and the specific prohibitions in paragraph (b) of this section apply to each User introducing pollutants into a POTW whether or not the User is subject to other National Pretreatment Standards or any national, State, or local Pretreatment Requirements.

(2) Affirmative Defenses. A User shall have an affirmative defense in any action brought against it alleging a violation of the general prohibitions established in paragraph (a)(1) of this section and the specific prohibitions in paragraphs (b)(3), (b)(4), (b)(5), (b)(6), and (b)(7) of this section where the User can demonstrate that:

(i) It did not know or have reason to know that its Discharge, alone or in conjunction with a discharge or discharges from other sources, would cause Pass Through or Interference; and

(ii)(A) A local limit designed to prevent Pass Through and/or Interference, as the case may be, was developed in accordance with paragraph (c) of this section for each pollutant in the User's Discharge that caused Pass Through or Interference, and the User was in compliance with each such local limit directly prior to and during the Pass Through or Interference; or

(B) If a local limit designed to prevent Pass Through and/or Interference, as the case may be, has not been developed in accordance with paragraph (c) of this section for the pollutant(s) that caused the Pass Through or Interference, the User's Discharge directly prior to and during the Pass Through or Interference did not change substantially in nature or constituents from the User's prior discharge activity when the POTW was regularly in compliance with the POTW's NPDES permit requirements and, in the case of Interference, applicable requirements for sewage sludge use or disposal.

(b) Specific prohibitions. In addition, the following pollutants shall not be introduced into a POTW:

(1) Pollutants which create a fire or explosion hazard in the POTW, including, but not limited to, wastestreams with a closed cup flashpoint of less than 140 degrees Fahrenheit or 60 degrees Centigrade using the test methods specified in 40 CFR 261.21.

(2) Pollutants which will cause corrosive structural damage to the POTW, but in no case Discharges with pH lower than 5.0, unless the works is specifically designed to accommodate such Discharges;

(3) Solid or viscous pollutants in amounts which will cause obstruction to the flow in the POTW resulting in Interference;

(4) Any pollutant, including oxygen demanding pollutants (BOD, etc.) released in a Discharge at a flow rate and/or pollutant concentration which will cause Interference with the POTW.

(5) Heat in amounts which will inhibit biological activity in the POTW resulting in Interference, but in no case heat in such quantities that the temperature at the POTW Treatment Plant exceeds 40[degrees]C (104[degrees]F) unless the Approval Authority, upon request of the POTW, approves alternate temperature limits.

(6) Petroleum oil, nonbiodegradable cutting oil, or products of mineral oil origin in amounts that will cause interference or pass through;

(7) Pollutants which result in the presence of toxic gases, vapors, or fumes within the POTW in a quantity that may cause acute worker health and safety problems;

(8) Any trucked or hauled pollutants, except at discharge points designated by the POTW.

(c) When specific limits must be developed by POTW. (1) Each POTW developing a POTW Pretreatment Program pursuant to § 403.8 shall develop and enforce specific limits to implement the prohibitions listed in paragraphs (a)(1) and (b) of this section. Each POTW with an approved pretreatment program shall continue to develop these limits as necessary and effectively enforce such limits.

(2) All other POTW's shall, in cases where pollutants contributed by User(s) result in Interference or Pass-Through, and such violation is likely to recur, develop and enforce specific effluent limits for Industrial User(s), and all other users, as appropriate, which, together with appropriate changes in the POTW Treatment Plant's facilities or operation, are necessary to ensure renewed and continued compliance with the POTW's NPDES permit or sludge use or disposal practices.

(3) Specific effluent limits shall not be developed and enforced without individual notice to persons or groups who have requested such notice and an opportunity to respond.

(d) Local limits. Where specific prohibitions or limits on pollutants or pollutant parameters are developed by a POTW in accordance with paragraph (c) above, such limits shall be deemed Pretreatment Standards for the purposes of section 307(d) of the Act.

(e) EPA enforcement actions under section 309(f) of the Clean Water Act.

If, within 30 days after notice of an Interference or Pass Through violation has been sent by EPA to the POTW, and to persons or groups who have requested such notice, the POTW fails to commence appropriate enforcement action to correct the violation, EPA may take appropriate enforcement action under the authority provided in section 309(f) of the Clean Water Act.

(f) [Removed. See 60 FR 33932, June 29, 1995.]

Source

[46 FR 9439, Jan. 28, 1981, as amended at 51 FR 20430, June 4, 1986; 52 FR 1600, Jan. 14, 1987; 55 FR 30129, July 24, 1990; 60 FR 33932, June 29, 1995]

§ 403.6 National pretreatment standards: Categorical standards.

National pretreatment standards specifying quantities or concentrations of pollutants or pollutant properties which may be discharged to a POTW by existing or new industrial users in specific industrial subcategories will be established as separate regulations under the appropriate subpart of 40 CFR chapter I, subchapter N. These standards, unless specifically noted

otherwise, shall be in addition to all applicable pretreatment standards and requirements set forth in this part.

(a) Category Determination Request--(1) Application Deadline. Within 60 days after the effective date of a Pretreatment Standard for a subcategory under which an Industrial User may be included, the Industrial User or POTW may request that the Water Management Division Director or Director, as appropriate, provide written certification on whether the Industrial User falls within that particular subcategory. If an existing Industrial User adds or changes a process or operation which may be included in a subcategory, the existing Industrial User must request this certification prior to commencing discharge from the added or changed processes or operation. A New Source must request this certification prior to commencing discharge. Where a request for certification is submitted by a POTW, the POTW shall notify any affected Industrial User of such submission. The Industrial User may provide written comments on the POTW submission to the Water Management Division Director or Director, as appropriate, within 30 days of notification.

(2) Contents of Application. Each request shall contain a statement:

(i) Describing which subcategories might be applicable; and

(ii) Citing evidence and reasons why a particular subcategory is applicable and why others are not applicable. Any person signing the application statement submitted pursuant to this section shall make the following certification:

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

(3) Deficient requests. The Water Management Division Director or Director will only act on written requests for determinations that contain all of the information required. Persons who have made incomplete submissions will be notified by the Water Management Division Director or Director that their requests are deficient and, unless the time period is extended, will be given 30 days to correct the deficiency. If the deficiency is not corrected within 30 days or within an extended period allowed by the Water Management Division Director or the Director, the request for a determination shall be denied.

(4) Final decision. (i) When the Water Management Division Director or Director receives a submittal he or she will, after determining that it contains all of the information required by paragraph (2) of this section, consider the submission, any additional evidence that may have been requested, and any other available information relevant to the request. The Water Management Division Director or Director will then make a written determination of the applicable subcategory and state the reasons for the determination.

(ii) Where the request is submitted to the Director, the Director shall forward the determination described in this paragraph to the Water Management Division Director who may make a final determination. The Water Management Division Director may waive receipt of these determinations. If the Water Management Division Director does not modify the Director's decision within 60 days after receipt thereof, or if the Water Management Division Director waives receipt of the determination, the Director's decision is final.

(iii) Where the request is submitted by the Industrial User or POTW to the Water Management Division Director or where the Water Management Division Director elects to modify the Director's decision, the Water Management Division Director's decision will be final.

(iv) The Water Management Division Director or Director, as appropriate, shall send a copy of the determination to the affected Industrial User and the POTW. Where the final determination is made by the Water Management Division Director, he or she shall send a copy of the determination to the Director.

(5) Requests for hearing and/or legal decision. Within 30 days following the date of receipt of notice of the final determination as provided for by paragraph (a)(4)(iv) of this section, the Requester may submit a petition to reconsider or contest the decision to the Regional Administrator who shall act on such petition expeditiously and state the reasons for his or her determination in writing.

(b) Deadline for Compliance with Categorical Standards. Compliance by existing sources with categorical Pretreatment Standards shall be within 3 years of the date the Standard is effective unless a shorter compliance time is specified in the appropriate subpart of 40 CFR chapter I, subchapter N. Direct dischargers with NPDES permits modified or reissued to provide a variance pursuant to section 301(i)(2) of the Act shall be required to meet compliance dates set in any applicable categorical Pretreatment Standard. Existing sources which become Industrial Users subsequent to promulgation of an applicable categorical Pretreatment Standard shall be considered existing Industrial Users except where such sources meet the definition of a New Source as defined in § 403.3(k). New Sources shall install and have in operating condition, and shall "start-up" all pollution control equipment required to meet applicable Pretreatment Standards before beginning to Discharge. Within the shortest feasible time (not to exceed 90 days), New Sources must meet all applicable Pretreatment Standards.

(c)(1) Concentration and mass limits. Pollutant discharge limits in categorical Pretreatment Standards will be expressed either as concentration or mass limits. Wherever possible, where concentration limits are specified in standards, equivalent mass limits will be provided so that local, State or Federal authorities responsible for enforcement may use either concentration or mass limits. Limits in categorical Pretreatment Standards shall apply to the effluent of the process regulated by the Standard, or as otherwise specified by the standard.

(2) When the limits in a categorical Pretreatment Standard are expressed only in terms of mass of pollutant per unit of production, the Control Authority may convert the limits to equivalent limitations expressed either as mass of pollutant discharged per day of effluent concentration for purposes of calculating effluent limitations applicable to individual Industrial Users.

(3) A Control Authority calculating equivalent mass-per-day limitations under paragraph (c)(2) of this section shall calculate such limitations by multiplying the limits in the Standard by the Industrial User's average rate of production. This average rate of production shall be based not upon the designed production capacity but rather upon a reasonable measure of the Industrial User's actual long-term daily production, such as the average daily production during a representative year. For new sources, actual production shall be estimated using projected production.

(4) A Control Authority calculating equivalent concentration limitations under paragraph (c)(2) of this section shall calculate such limitations by dividing the mass limitations derived under paragraph (c)(3) of this section by the average daily flow rate of the Industrial User's regulated process wastewater. This average daily flow rate shall be based upon a reasonable measure of the Industrial User's actual long-term average flow rate, such as the average daily flow rate during the representative year.

(5) Equivalent limitations calculated in accordance with paragraphs (c)(3) and (c)(4) of this section shall be deemed Pretreatment Standards for the purposes of section 307(d) of the Act and this part. Industrial Users will be required to comply with the equivalent limitations in lieu of the promulgated categorical standards from which the equivalent limitations were derived.

(6) Many categorical pretreatment standards specify one limit for calculating maximum daily discharge limitations and a second limit for calculating maximum monthly average, or 4-day average, limitations. Where such Standards are being applied, the same production of flow figure shall be used in calculating both types of equivalent limitations.

(7) Any Industrial User operating under a control mechanism incorporating equivalent mass or concentration limits calculated from a production based standard shall notify the Control Authority within two (2) business days after the User has a reasonable basis to know that the production level will significantly change within the next calendar month. Any User not notifying

the Control Authority of such anticipated change will be required to meet the mass or concentration limits in its control mechanism that were based on the original estimate of the long term average production rate.

(d) Dilution Prohibited as Substitute for Treatment. Except where expressly authorized to do so by an applicable Pretreatment Standard or Requirement, no Industrial User shall ever increase the use of process water, or in any other way attempt to dilute a discharge as a partial or complete substitute for adequate treatment to achieve compliance with a Pretreatment Standard or Requirement. The Control Authority (as defined in § 403.12(a)) may impose mass limitations on Industrial Users which are using dilution to meet applicable Pretreatment Standards or Requirements, or in other cases where the imposition of mass limitations is appropriate.

(e) Combined wastestream formula. Where process effluent is mixed prior to treatment with wastewaters other than those generated by the regulated process, fixed alternative discharge limits may be derived by the Control Authority, as defined in § 403.12(a), or by the Industrial User with the written concurrence of the Control Authority. These alternative limits shall be applied to the mixed effluent. When deriving alternative categorical limits, the Control Authority or Industrial User shall calculate both an alternative daily maximum value using the daily maximum value(s) specified in the appropriate categorical Pretreatment Standard(s) and an alternative consecutive sampling day average value using the monthly average value(s) specified in the appropriate categorical Pretreatment Standard(s). The Industrial User shall comply with the alternative daily maximum and monthly average limits fixed by the Control Authority until the Control Authority modifies the limits or approves an Industrial User modification request. Modification is authorized whenever there is a material or significant change in the values used in the calculation to fix alternative limits for the regulated pollutant. An Industrial User must immediately report any such material or significant change to the Control Authority. Where appropriate new alternative categorical limits shall be calculated within 30 days.

(1) Alternative limit calculation. For purposes of these formulas, the "average daily flow" means a reasonable measure of the average daily flow for a 30-day period. For new sources, flows shall be estimated using projected values. The alternative limit for a specified pollutant will be derived by the use of either of the following formulas:

(i) Alternative concentration limit.

(1) The pollutants of concern are not detectable in the effluent from the Industrial User (paragraph (8)(a)(iii));

(2) The pollutants of concern are present only in trace amounts and are neither causing nor likely to cause toxic effects (paragraph (8)(a)(iii));

(3) The pollutants of concern are present in amounts too small to be effectively reduced by technologies known to the Administrator (paragraph (8)(a)(iii)); or

(4) The wastestream contains only pollutants which are compatible with the POTW (paragraph (8)(b)(i)).

$F[T]$] The average daily flow (at least a 30-day average) through the combined treatment facility (includes $F[i]$, $F[D]$ and unregulated streams).

N = The total number of regulated streams.

(ii) Alternative mass limit.

(1) The pollutants of concern are not detectable in the effluent from the Industrial User (paragraph (8)(a)(iii));

(2) The pollutants of concern are present only in trace amounts and are neither causing nor likely to cause toxic effects (paragraph (8)(a)(iii));

(3) The pollutants of concern are present in amounts too small to be effectively reduced by technologies known to the Administrator (paragraph (8)(a)(iii)); or

(4) The wastestream contains only pollutants which are compatible with the POTW (paragraph (8)(b)(i)).

F[T] = The average flow (at least a 30-day average) through the combined treatment facility (includes F[i], F[D] and unregulated streams).

N = The total number of regulated streams.

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(2) The pollutants of concern are present only in trace amounts and are neither causing nor likely to cause toxic effects (paragraph (8)(a)(iii));

(3) The pollutants of concern are present in amounts too small to be effectively reduced by technologies known to the Administrator (paragraph (8)(a)(iii)); or

(4) The wastestream contains only pollutants which are compatible with the POTW (paragraph (8)(b)(i)).

F[T] = The average flow (at least a 30-day average) through the combined treatment facility (includes F[i], F[D] and unregulated streams).

N = The total number of regulated streams.

(2) Alternate limits below detection limit. An alternative pretreatment limit may not be used if the alternative limit is below the analytical detection limit for any of the regulated pollutants.

(3) Self-monitoring. Self-monitoring required to insure compliance with the alternative categorical limit shall be conducted in accordance with the requirements of § 403.12(g).

(4) Choice of monitoring location. Where a treated regulated process wastestream is combined prior to treatment with wastewaters other than those generated by the regulated process, the Industrial User may monitor either the segregated process wastestream or the combined wastestream for the purpose of determining compliance with applicable Pretreatment Standards. If the Industrial User chooses to monitor the segregated process wastestream, it shall apply the applicable categorical Pretreatment Standard. If the User chooses to monitor the combined wastestream, it shall apply an alternative discharge limit calculated using the combined wastestream formula as provided in this section. The Industrial User may change monitoring points only after receiving approval from the Control Authority. The Control Authority shall ensure that any change in an Industrial User's monitoring point(s) will not allow the User to substitute dilution for adequate treatment to achieve compliance with applicable Standards.

(Information collection requirements are approved by the Office of Management and Budget under control number 2040-0009)

Source

[46 FR 9439, Jan. 28, 1981, as amended at 49 FR 21037, May 17, 1984; 49 FR 31224, Aug. 3, 1984; 51 FR 20430, June 4, 1986; 51 FR 23760, July 1, 1986; 53 FR 40610, Oct. 17, 1988; 55 FR 30129, July 24, 1990]

§ 403.7 Removal credits. (a) Introduction--(1) Definitions. For the purpose of this section:

(i) Removal means a reduction in the amount of a pollutant in the POTW's effluent or alteration of the nature of a pollutant during treatment at the POTW. The reduction or alteration can be obtained by physical, chemical or biological means and may be the result of specifically designed POTW capabilities or may be incidental to the operation of the treatment system. Removal as used in this subpart shall not mean dilution of a pollutant in the POTW.

(ii) Sludge Requirements shall mean the following statutory provisions and regulations or permits issued there under (or more stringent State or local regulations): Section 405 of the Clean Water Act; the Solid Waste Disposal Act (SWDA) (including title II more commonly referred to as the Resource Conservation Recovery Act (RCRA) and State regulations contained in any State sludge management plan prepared pursuant to subtitle D of SWDA); the Clean Air Act; the Toxic Substances Control Act; and the Marine Protection, Research and Sanctuaries Act.

(2) General. Any POTW receiving wastes from an Industrial User to which a categorical Pretreatment Standard(s) applies may, at its discretion and subject to the conditions of this section, grant removal credits to reflect removal by the POTW of pollutants specified in the categorical Pretreatment Standard(s). The POTW may grant a removal credit equal to or, at its discretion, less than its consistent removal rate. Upon being granted a removal credit, each affected Industrial User shall calculate its revised discharge limits in accordance with paragraph (a)(4) of this section. Removal credits may only be given for indicator or surrogate pollutants regulated in a categorical Pretreatment Standard if the categorical Pretreatment Standard so specifies.

(3) Conditions for authorization to give removal credits. A POTW is authorized to give removal credits only if the following conditions are met:

(i) Application. The POTW applies for, and receives, authorization from the Approval Authority to give a removal credit in accordance with the requirements and procedures specified in paragraph (e) of this section.

(ii) Consistent removal determination. The POTW demonstrates and continues to achieve consistent removal of the pollutant in accordance with paragraph (b) of this section.

(iii) POTW local pretreatment program. The POTW has an approved pretreatment program in accordance with and to the extent required by part 403; provided, however, a POTW which does not have an approved pretreatment program may, pending approval of such a program, conditionally give credits as provided in paragraph (d) of this section.

(iv) Sludge requirements. The granting of removal credits will not cause the POTW to violate the local, State and Federal Sludge Requirements which apply to the sludge management method chosen by the POTW. Alternatively, the POTW can demonstrate to the Approval Authority that even though it is not presently in compliance with applicable Sludge Requirements, it will be in compliance when the Industrial User(s) to whom the removal credit would apply is required to meet its categorical Pretreatment Standard(s) as modified by the removal credit. If granting removal credits forces a POTW to incur greater sludge management costs than would be incurred in the absence of granting removal credits, the additional sludge management costs will not be eligible for EPA grant assistance. Removal credits may be made available for the following pollutants.

(A) For any pollutant listed in appendix G section I of this part for the use or disposal practice employed by the POTW, when the requirements in 40 CFR part 503 for that practice are met.

(B) For any pollutant listed in appendix G section II of this part for the use or disposal practice employed by the POTW when the concentration for a pollutant listed in appendix G section II of this part in the sewage sludge that is used or disposed does not exceed the concentration for the pollutant in appendix G section II of this part.

(C) For any pollutant in sewage sludge when the POTW disposes all of its sewage sludge in a municipal solid waste landfill unit that meets the criteria in 40 CFR part 258.

(v) NPDES permit limitations. The granting of removal credits will not cause a violation of the POTW's permit limitations or conditions. Alternatively, the POTW can demonstrate to the Approval Authority that even though it is not presently in compliance with applicable limitations and conditions in its NPDES permit, it will be in compliance when the Industrial User(s) to whom the removal credit would apply is required to meet its categorical Pretreatment Standard(s), as modified by the removal credit provision.

(4) Calculation of revised discharge limits. Revised discharge limits for a specific pollutant shall be derived by use of the following formula:

$$y = \frac{x}{1 - r}$$

where: discharge limit specified in the applicable categorical Pretreatment Standard
r=removal credit for that pollutant as established under paragraph (b) of this section (percentage removal expressed as a proportion, i.e., a number between 0 and 1)

y=revised discharge limit for the specified pollutant (expressed in same units as x)

(b) Establishment of Removal Credits; Demonstration of Consistent Removal--(1) Definition of Consistent Removal. "Consistent Removal" shall mean the average of the lowest 50 percent of the removal measured according to paragraph (b)(2) of this section. All sample data obtained for the measured pollutant during the time period prescribed in paragraph (b)(2) of this section must be reported and used in computing Consistent Removal. If a substance is measurable in the influent but not in the effluent, the effluent level may be assumed to be the limit of measurement, and those data may be used by the POTW at its discretion and subject to approval by the Approval Authority. If the substance is not measurable in the influent, the data may not be used. Where the number of samples with concentrations equal to or above the limit of measurement is between 8 and 12, the average of the lowest 6 removals shall be used. If there are less than 8 samples with concentrations equal to or above the limit of measurement, the Approval Authority may approve alternate means for demonstrating Consistent Removal. The term "measurement" refers to the ability of the analytical method or protocol to quantify as well as identify the presence of the substance in question.

(2) Consistent Removal Data. Influent and effluent operational data demonstrating Consistent Removal or other information, as provided for in paragraph (b)(1) of this section, which demonstrates Consistent Removal of the pollutants for which discharge limit revisions are proposed. This data shall meet the following requirements:

(i) Representative Data; Seasonal. The data shall be representative of yearly and seasonal conditions to which the POTW is subjected for each pollutant for which a discharge limit revision is proposed.

(ii) Representative Data; Quality and Quantity. The data shall be representative of the quality and quantity of normal effluent and influent flow if such data can be obtained. If such data are unobtainable, alternate data or information may be presented for approval to demonstrate Consistent Removal as provided for in paragraph (b)(1) of this section.

(iii) Sampling Procedures: Composite. (A) The influent and effluent operational data shall be obtained through 24-hour flow-proportional composite samples. Sampling may be done manually or automatically, and discretely or continuously. For discrete sampling, at least 12 aliquots shall be composited. Discrete sampling may be flow-proportioned either by varying the time interval between each aliquot or the volume of each aliquot. All composites must be flow-proportional to each stream flow at time of collection of influent aliquot or to the total influent flow since the previous influent aliquot. Volatile pollutant aliquots must be combined in the laboratory immediately before analysis.

(B)(1) Twelve samples shall be taken at approximately equal intervals throughout one full year. Sampling must be evenly distributed over the days of the week so as to include no-workdays as well as workdays. If the Approval Authority determines that this schedule will not be most representative of the actual operation of the POTW Treatment Plant, an alternative sampling schedule will be approved.

(2) In addition, upon the Approval Authority's concurrence, a POTW may utilize an historical data base amassed prior to the effective date of this section provide that such data otherwise meet the requirements of this paragraph. In order for the historical data base to be approved it must present a statistically valid description of daily, weekly and seasonal sewage treatment plant loadings and performance for at least one year.

(C) Effluent sample collection need not be delayed to compensate for hydraulic detention unless the POTW elects to include detention time compensation or unless the Approval Authority requires detention time compensation. The Approval Authority may require that each effluent sample be taken approximately one detention time later than the corresponding influent sample when failure to do so would result in an unrepresentative portrayal of actual POTW operation.

The detention period is to be based on a 24-hour average daily flow value. The average daily flow used will be based upon the average of the daily flows during the same month of the previous year.

(iv) Sampling Procedures: Grab. Where composite sampling is not an appropriate sampling technique, a grab sample(s) shall be taken to obtain influent and effluent operational data. Collection of influent grab samples should precede collection of effluent samples by approximately one detention period. The detention period is to be based on a 24-hour average daily flow value. The average daily flow used will be based upon the average of the daily flows during the same month of the previous year. Grab samples will be required, for example, where the parameters being evaluated are those, such as cyanide and phenol, which may not be held for any extended period because of biological, chemical or physical interactions which take place after sample collection and affect the results. A grab sample is an individual sample collected over a period of time not exceeding 15 minutes.

(v) Analytical methods. The sampling referred to in paragraphs (b)(2) (i) through (iv) of this section and an analysis of these samples shall be performed in accordance with the techniques prescribed in 40 CFR part 136 and amendments thereto. Where 40 CFR part 136 does not contain sampling or analytical techniques for the pollutant in question, or where the Administrator determines that the part 136 sampling and analytical techniques are inappropriate for the pollutant in question, sampling and analysis shall be performed using validated analytical methods or any other applicable sampling and analytical procedures, including procedures suggested by the POTW or other parties, approved by the Administrator.

(vi) Calculation of removal. All data acquired under the provisions of this section must be submitted to the Approval Authority. Removal for a specific pollutant shall be determined either, for each sample, by measuring the difference between the concentrations of the pollutant in the influent and effluent of the POTW and expressing the difference as a percent of the influent concentration, or, where such data cannot be obtained, Removal may be demonstrated using other data or procedures subject to concurrence by the Approval Authority as provided for in paragraph (b)(1) of this section.

(c) Provisional credits. For pollutants which are not being discharged currently (i.e., new or modified facilities, or production changes) the POTW may apply for authorization to give removal credits prior to the initial discharge of the pollutant. Consistent removal shall be based provisionally on data from treatability studies or demonstrated removal at other treatment facilities where the quality and quantity of influent are similar. Within 18 months after the commencement of discharge of pollutants in question, consistent removal must be demonstrated pursuant to the requirements of paragraph (b) of this section. If, within 18 months after the commencement of the discharge of the pollutant in question, the POTW cannot demonstrate consistent removal pursuant to the requirements of paragraph (b) of this section, the authority to grant provisional removal credits shall be terminated by the Approval Authority and all Industrial Users to whom the revised discharge limits had been applied shall achieve compliance with the applicable categorical Pretreatment Standard(s) within a reasonable time, not to exceed the period of time prescribed in the applicable categorical Pretreatment Standard(s), as may be specified by the Approval Authority.

(d) Exception to POTW Pretreatment Program Requirement. A POTW required to develop a local pretreatment program by § 403.8 may conditionally give removal credits pending approval of such a program in accordance with the following terms and conditions:

(1) All Industrial Users who are currently subject to a categorical Pretreatment Standard and who wish conditionally to receive a removal credit must submit to the POTW the information required in § 403.12(b)(1) through (7) (except new or modified industrial users must only submit the information required by § 403.12(b)(1) through (6)), pertaining to the categorical Pretreatment Standard as modified by the removal credit. The Industrial Users shall indicate what additional technology, if any, will be needed to comply with the categorical Pretreatment Standard(s) as modified by the removal credit;

(2) The POTW must have submitted to the Approval Authority an application for pretreatment program approval meeting the requirements of §§ 403.8 and 403.9 in a timely manner, not to exceed the time limitation set forth in a compliance schedule for development of a pretreatment program included in the POTW's NPDES permit, but in no case later than July 1, 1983, where no permit deadline exists;

(3) The POTW must:

(i) Compile and submit data demonstrating its consistent removal in accordance with paragraph (b) of this section;

(ii) Comply with the conditions specified in paragraph (a)(3) of this section; and

(iii) Submit a complete application for removal credit authority in accordance with paragraph (e) of this section;

(4) If a POTW receives authority to grant conditional removal credits and the Approval Authority subsequently makes a final determination, after appropriate notice, that the POTW failed to comply with the conditions in paragraphs (d)(2) and (3) of this section, the authority to grant conditional removal credits shall be terminated by the Approval Authority and all industrial Users to whom the revised discharge limits had been applied shall achieve compliance with the applicable categorical Pretreatment Standard(s) within a reasonable time, not to exceed the period of time prescribed in the applicable categorical Pretreatment Standard(s), as may be specified by the Approval Authority.

(5) If a POTW grants conditional removal credits and the POTW or the Approval Authority subsequently makes a final determination, after appropriate notice, that the Industrial User(s) failed to comply with the conditions in paragraph (d)(1) of this section, the conditional credit shall be terminated by the POTW or the Approval Authority for the non-complying Industrial User(s) and the Industrial User(s) to whom the revised discharge limits had been applied shall achieve compliance with the applicable categorical Pretreatment Standard(s) within a reasonable time, not to exceed the period of time prescribed in the applicable categorical Pretreatment Standard(s), as may be specified by the Approval Authority. The conditional credit shall not be terminated where a violation of the provisions of this paragraph results from causes entirely outside of the control of the Industrial User(s) or the Industrial User(s) had demonstrated substantial compliance.

(6) The Approval Authority may elect not to review an application for conditional removal credit authority upon receipt of such application, in which case the conditionally revised discharge limits will remain in effect until reviewed by the Approval Authority. This review may occur at any time in accordance with the procedures of § 403.11, but in no event later than the time of any pretreatment program approval or any NPDES permit re-issuance there under.

(e) POTW application for authorization to give removal credits and Approval Authority review--

(1) Who must apply. Any POTW that wants to give a removal credit must apply for authorization from the Approval Authority.

(2) To whom application is made. An application for authorization to give removal credits (or modify existing ones) shall be submitted by the POTW to the Approval Authority.

(3) When to apply. A POTW may apply for authorization to give or modify removal credits at any time.

(4) Contents of the Application. An application for authorization to give removal credits must be supported by the following information:

(i) List of pollutants. A list of pollutants for which removal credits are proposed.

(ii) Consistent Removal Data. The data required pursuant to paragraph (b) of this section.

(iii) Calculation of revised discharge limits. Proposed revised discharge limits for each affected subcategory of Industrial Users calculated in accordance with paragraph (a)(4) of this section.

(iv) Local Pretreatment Program Certification. A certification that the POTW has an approved local pretreatment program or qualifies for the exception to this requirement found at paragraph (d) of this section.

(v) Sludge Management Certification. A specific description of the POTW's current methods of using or disposing of its sludge and a certification that the granting of removal credits will not cause a violation of the sludge requirements identified in paragraph (a)(3)(iv) of this section.

(vi) NPDES Permit Limit Certification. A certification that the granting of removal credits will not cause a violation of the POTW's NPDES permit limits and conditions as required in paragraph (a)(3)(v) of this section.

(5) Approval Authority Review. The Approval Authority shall review the POTW's application for authorization to give or modify removal credits in accordance with the procedures of § 403.11 and shall, in no event, have more than 180 days from public notice of an application to complete review.

(6) EPA review of State removal credit approvals. Where the NPDES State has an approved pretreatment program, the Regional Administrator may agree in the Memorandum of Agreement under 40 CFR 123.24(d) to waive the right to review and object to submissions for authority to grant removal credits. Such an agreement shall not restrict the Regional Administrator's right to comment upon or object to permits issued to POTW's except to the extent 40 CFR 123.24(d) allows such restriction.

(7) Nothing in these regulations precludes an Industrial User or other interested party from assisting the POTW in preparing and presenting the information necessary to apply for authorization.

(f) Continuation and withdrawal of authorization--(1) Effect of authorization. (i) Once a POTW has received authorization to grant removal credits for a particular pollutant regulated in a categorical Pretreatment Standard it may automatically extend that removal credit to the same pollutant when it is regulated in other categorical standards, unless granting the removal credit will cause the POTW to violate the sludge requirements identified in paragraph (a)(3)(iv) of this section or its NPDES permit limits and conditions as required by paragraph (a)(3)(v) of this section. If a POTW elects at a later time to extend removal credits to a certain categorical Pretreatment Standard, industrial subcategory or one or more Industrial Users that initially were not granted removal credits, it must notify the Approval Authority.

(2) Inclusion in POTW permit. Once authority is granted, the removal credits shall be included in the POTW's NPDES Permit as soon as possible and shall become an enforceable requirement of the POTW's NPDES permit. The removal credits will remain in effect for the term of the POTW's NPDES permit, provided the POTW maintains compliance with the conditions specified in paragraph (f)(4) of this section.

(3) Compliance monitoring. Following authorization to give removal credits, a POTW shall continue to monitor and report on (at such intervals as may be specified by the Approval Authority, but in no case less than once per year) the POTW's removal capabilities. A minimum of one representative sample per month during the reporting period is required, and all sampling data must be included in the POTW's compliance report.

(4) Modification or withdrawal of removal credits--(i) Notice of POTW. The Approval Authority shall notify the POTW if, on the basis of pollutant removal capability reports received pursuant to paragraph (f)(3) of this section or other relevant information available to it, the Approval Authority determines:

(A) That one or more of the discharge limit revisions made by the POTW, of the POTW itself, no longer meets the requirements of this section, or

(B) That such discharge limit revisions are causing a violation of any conditions or limits contained in the POTW's NPDES Permit.

(ii) Corrective action. If appropriate corrective action is not taken within a reasonable time, not to exceed 60 days unless the POTW or the affected Industrial Users demonstrate that a longer time period is reasonably necessary to undertake the appropriate corrective action, the Approval Authority shall either withdraw such discharge limits or require modifications in the revised discharge limits.

(iii) Public notice of withdrawal or modification. The Approval Authority shall not withdraw or modify revised discharge limits unless it shall first have notified the POTW and all Industrial Users to whom revised discharge limits have been applied, and made public, in writing, the reasons for such withdrawal or modification, and an opportunity is provided for a hearing. Following such notice and withdrawal or modification, all Industrial Users to whom revised discharge limits had been applied, shall be subject to the modified discharge limits or the discharge limits prescribed in the applicable categorical Pretreatment Standards, as appropriate, and shall achieve compliance with such limits within a reasonable time (not to exceed the period of time prescribed in the applicable categorical Pretreatment Standard(s) as may be specified by the Approval Authority.

(g) Removal credits in State-run pretreatment programs under § 403.10(e). Where an NPDES State with an approved pretreatment program elects to implement a local pretreatment program in lieu of requiring the POTW to develop such a program (as provided in § 403.10(e)), the POTW will not be required to develop a pretreatment program as a precondition to obtaining authorization to give removal credits. The POTW will, however, be required to comply with the other conditions of paragraph (a)(3) of this section.

(h) Compensation for overflow. "Overflow" means the intentional or unintentional diversion of flow from the POTW before the POTW Treatment Plant. POTWs which at least once annually Overflow untreated wastewater to receiving waters may claim Consistent Removal of a pollutant only by complying with either paragraph (h)(1) or (h)(2) of this section. However, this subsection shall not apply where Industrial User(s) can demonstrate that Overflow does not occur between the Industrial User(s) and the POTW Treatment Plant;

(1) The Industrial User provides containment or otherwise ceases or reduces Discharges from the regulated processes which contain the pollutant for which an allowance is requested during all circumstances in which an Overflow event can reasonably be expected to occur at the POTW or at a sewer to which the Industrial User is connected. Discharges must cease or be reduced, or pretreatment must be increased, to the extent necessary to compensate for the removal not being provided by the POTW. Allowances under this provision will only be granted where the POTW submits to the Approval Authority evidence that:

(i) All Industrial Users to which the POTW proposes to apply this provision have demonstrated the ability to contain or otherwise cease or reduce, during circumstances in which an Overflow event can reasonably be expected to occur, Discharges from the regulated processes which contain pollutants for which an allowance is requested;

(ii) The POTW has identified circumstances in which an Overflow event can reasonably be expected to occur, and has a notification or other viable plan to insure that Industrial Users will learn of an impending Overflow in sufficient time to contain, cease or reduce Discharging to prevent untreated Overflows from occurring. The POTW must also demonstrate that it will monitor and verify the data required in paragraph (h)(1)(iii) of this section, to insure that Industrial Users are containing, ceasing or reducing operations during POTW System Overflow; and

(iii) All Industrial Users to which the POTW proposes to apply this provision have demonstrated the ability and commitment to collect and make available, upon request by the POTW, State Director or EPA Regional Administrator, daily flow reports or other data sufficient to demonstrate that all Discharges from regulated processes containing the pollutant for which the allowance is requested were contained, reduced or otherwise ceased, as appropriate, during all circumstances in which an Overflow event was reasonably expected to occur; or

(2)(i) The Consistent Removal claimed is reduced pursuant to the following equation:

$$\begin{array}{l} 8760-Z \\ rc = r m \text{ -----} \\ 8760 \end{array}$$

Where:

rm = POTW's Consistent Removal rate for that pollutant as established under paragraphs (a)(1) and (b)(2) of this section

rc = removal corrected by the Overflow factor

Z = hours per year that Overflow occurred between the Industrial User(s) and the POTW Treatment Plant, the hours either to be shown in the POTW's current NPDES permit application or the hours, as demonstrated by verifiable techniques, that a particular Industrial User's Discharge Overflows between the Industrial User and the POTW Treatment Plant; and

(ii) After July 1, 1983, Consistent Removal may be claimed only where efforts to correct the conditions resulting in untreated Discharges by the POTW are underway in accordance with the policy and procedures set forth in "PRM 75-34" or "Program Guidance Memorandum-61" (same document) published on December 16, 1975, by EPA Office of Water Program Operations (WH-546). (See appendix A.) Revisions to discharge limits in categorical Pretreatment Standards may not be made where efforts have not been committed to by the POTW to minimize pollution from Overflows. At minimum, by July 1, 1983, the POTW must have completed the analysis required by PRM 75-34 and be making an effort to implement the plan.

(iii) If, by July 1, 1983, a POTW has begun the PRM 75-34 analysis but due to circumstances beyond its control has not completed it, Consistent Removal, subject to the approval of the Approval Authority, may continue to be claimed according to the formula in paragraph (h)(2)(i) of this section as long as the POTW acts in a timely fashion to complete the analysis and makes an effort to implement the non-structural cost-effective measures identified by the analysis; and so long as the POTW has expressed its willingness to apply, after completing the analysis, for a construction grant necessary to implement any other cost-effective Overflow controls identified in the analysis should Federal funds become available, so applies for such funds, and proceeds with the required construction in an expeditious manner. In addition, Consistent Removal may, subject to the approval of the Approval Authority, continue to be claimed according to the formula in paragraph (h)(2)(i) of this section where the POTW has completed and the Approval Authority has accepted the analysis required by PRM 75-34 and the POTW has requested inclusion in its NPDES permit of an acceptable compliance schedule providing for timely implementation of cost-effective measures identified in the analysis. (In considering what is timely implementation, the Approval Authority shall consider the availability of funds, cost of control measures, and seriousness of the water quality problem.)

(Information collection requirements are approved by the Office of Management and Budget under control number 2040-0009)

Source

[49 FR 31221, Aug. 3, 1984, as amended at 51 FR 20430, June 4, 1986; 53 FR 42435, Nov. 5, 1987; 58 FR 9386, Feb. 19, 1993; 58 FR 18017, Apr. 7, 1993]

§ 403.8 Pretreatment Program Requirements: Development and Implementation by POTW.

(a) POTWs required to develop a pretreatment program. Any POTW (or combination of POTWs operated by the same authority) with a total design flow greater than 5 million gallons per day (mgd) and receiving from Industrial Users pollutants which Pass Through or Interfere with the operation of the POTW or are otherwise subject to Pretreatment Standards will be required to establish a POTW Pretreatment Program unless the NPDES State exercises its option to assume local responsibilities as provided for in § 403.10(e). The Regional Administrator or Director may require that a POTW with a design flow of 5 mgd or less develop a POTW Pretreatment Program if he or she finds that the nature or volume of the industrial influent, treatment process upsets, violations of POTW effluent limitations, contamination of municipal sludge, or other circumstances warrant in order to prevent Interference with the POTW or Pass Through.

(b) **Deadline for Program Approval.** A POTW which meets the criteria of paragraph (a) of this section must receive approval of a POTW Pretreatment Program no later than 3 years after the re-issuance or modification of its existing NPDES permit but in no case later than July 1, 1983. POTWs whose NPDES permits are modified under section 301(h) of the Act shall have a Pretreatment Program within three (3) years as provided for in 40 CFR part 125, subpart G. POTWs identified after July 1, 1983 as being required to develop a POTW Pretreatment Program under paragraph (a) of this section shall develop and submit such a program for approval as soon as possible, but in no case later than one year after written notification from the Approval Authority of such identification. The POTW Pretreatment Program shall meet the criteria set forth in paragraph (f) of this section and shall be administered by the POTW to ensure compliance by Industrial Users with applicable Pretreatment Standards and Requirements.

(c) **Incorporation of approved programs in permits.** A POTW may develop an appropriate POTW Pretreatment Program any time before the time limit set forth in paragraph (b) of this section. The POTW's NPDES Permit will be reissued or modified by the NPDES State or EPA to incorporate the approved Program as enforceable conditions of the Permit. The modification of a POTW's NPDES Permit for the purposes of incorporating a POTW Pretreatment Program approved in accordance with the procedure in § 403.11 shall be deemed a minor Permit modification subject to the procedures in 40 CFR 122.63.

(d) **Incorporation of compliance schedules in permits.** [Reserved]

(e) **Cause for re-issuance or modification of Permits.** Under the authority of section 402(b)(1)(C) of the Act, the Approval Authority may modify, or alternatively, revoke and reissue a POTW's Permit in order to:

(1) Put the POTW on a compliance schedule for the development of a POTW Pretreatment Program where the addition of pollutants into a POTW by an Industrial User or combination of Industrial Users presents a substantial hazard to the functioning of the treatment works, quality of the receiving waters, human health, or the environment;

(2) Coordinate the issuance of a section 201 construction grant with the incorporation into a permit of a compliance schedule for POTW Pretreatment Program;

(3) Incorporate a modification of the permit approved under section 301(h) or 301(i) of the Act;

(4) Incorporate an approved POTW Pretreatment Program in the POTW permit; or

(5) Incorporate a compliance schedule for the development of a POTW pretreatment program in the POTW permit.

(6) Incorporate the removal credits (established under § 403.7) in the POTW permit.

(f) **POTW pretreatment requirements.** A POTW pretreatment program must be based on the following legal authority and include the following procedures. These authorities and procedures shall at all times be fully and effectively exercised and implemented.

(1) **Legal authority.** The POTW shall operate pursuant to legal authority enforceable in Federal, State or local courts, which authorizes or enables the POTW to apply and to enforce the requirements of sections 307 (b) and (c), and 402(b)(8) of the Act and any regulations implementing those sections. Such authority may be contained in a statute, ordinance, or series of contracts or joint powers agreements which the POTW is authorized to enact, enter into or implement, and which are authorized by State law. At a minimum, this legal authority shall enable the POTW to:

(i) Deny or condition new or increased contributions of pollutants, or changes in the nature of pollutants, to the POTW by Industrial Users where such contributions do not meet applicable Pretreatment Standards and Requirements or where such contributions would cause the POTW to violate its NPDES permit;

(ii) Require compliance with applicable Pretreatment Standards and Requirements by Industrial Users;

(iii) Control through permit, order, or similar means, the contribution to the POTW by each Industrial User to ensure compliance with applicable Pretreatment Standards and

Requirements. In the case of Industrial Users identified as significant under 40 CFR 403.3(t), this control shall be achieved through permits or equivalent individual control mechanisms issued to each such user. Such control mechanisms must be enforceable and contain, at a minimum, the following conditions:

- (A) Statement of duration (in no case more than five years);
- (B) Statement of non-transferability without, at a minimum, prior notification to the POTW and provision of a copy of the existing control mechanism to the new owner or operator;
- (C) Effluent limits based on applicable general pretreatment standards in part 403 of this chapter, categorical pretreatment standards, local limits, and State and local law;
- (D) Self-monitoring, sampling, reporting, notification and recordkeeping requirements, including an identification of the pollutants to be monitored, sampling location, sampling frequency, and sample type, based on the applicable general pretreatment standards in part 403 of this chapter, categorical pretreatment standards, local limits, and State and local law;
- (E) Statement of applicable civil and criminal penalties for violation of pretreatment standards and requirements, and any applicable compliance schedule. Such schedules may not extend the compliance date beyond applicable federal deadlines.

(iv) Require (A) the development of a compliance schedule by each Industrial User for the installation of technology required to meet applicable Pretreatment Standards and Requirements and (B) the submission of all notices and self-monitoring reports from Industrial Users as are necessary to assess and assure compliance by Industrial Users with Pretreatment Standards and Requirements, including but not limited to the reports required in § 403.12.

(v) Carry out all inspection, surveillance and monitoring procedures necessary to determine, independent of information supplied by Industrial Users, compliance or noncompliance with applicable Pretreatment Standards and Requirements by Industrial Users. Representatives of the POTW shall be authorized to enter any premises of any Industrial User in which a Discharge source or treatment system is located or in which records are required to be kept under § 403.12(m) to assure compliance with Pretreatment Standards. Such authority shall be at least as extensive as the authority provided under section 308 of the Act;

(vi)(A) Obtain remedies for noncompliance by any Industrial User with any Pretreatment Standard and Requirement. All POTW's shall be able to seek injunctive relief for noncompliance by Industrial Users with Pretreatment Standards and Requirements. All POTWs shall also have authority to seek or assess civil or criminal penalties in at least the amount of \$ 1,000 a day for each violation by Industrial Users of Pretreatment Standards and Requirements.

(B) Pretreatment requirements which will be enforced through the remedies set forth in paragraph (f)(1)(vi)(A) of this section, will include but not be limited to, the duty to allow or carry out inspections, entry, or monitoring activities; any rules, regulations, or orders issued by the POTW; any requirements set forth in individual control mechanisms issued by the POTW; or any reporting requirements imposed by the POTW or these regulations. The POTW shall have authority and procedures (after informal notice to the discharger) immediately and effectively to halt or prevent any discharge of pollutants to the POTW which reasonably appears to present an imminent endangerment to the health or welfare of persons. The POTW shall also have authority and procedures (which shall include notice to the affected industrial users and an opportunity to respond) to halt or prevent any discharge to the POTW which presents or may present an endangerment to the environment or which threatens to interfere with the operation of the POTW. The Approval Authority shall have authority to seek judicial relief and may also use administrative penalty authority when the POTW has sought a monetary penalty which the Approval Authority believes to be insufficient.

(vii) Comply with the confidentiality requirements set forth in § 403.14.

(2) Procedures. The POTW shall develop and implement procedures to ensure compliance with the requirements of a Pretreatment Program. At a minimum, these procedures shall enable the POTW to:

- (i) Identify and locate all possible Industrial Users which might be subject to the POTW Pretreatment Program. Any compilation, index or inventory of Industrial Users made under this paragraph shall be made available to the Regional Administrator or Director upon request;
- (ii) Identify the character and volume of pollutants contributed to the POTW by the Industrial Users identified under paragraph (f)(2)(i) of this section. This information shall be made available to the Regional Administrator or Director upon request;
- (iii) Notify Industrial Users identified under paragraph (f)(2)(i) of this section, of applicable Pretreatment Standards and any applicable requirements under sections 204(b) and 405 of the Act and subtitles C and D of the Resource Conservation and Recovery Act. Within 30 days of approval pursuant to 40 CFR 403.8(f)(6), of a list of significant industrial users, notify each significant industrial user of its status as such and of all requirements applicable to it as a result of such status.
- (iv) Receive and analyze self-monitoring reports and other notices submitted by Industrial Users in accordance with the self-monitoring requirements in § 403.12;
- (v) Randomly sample and analyze the effluent from industrial users and conduct surveillance activities in order to identify, independent of information supplied by industrial users, occasional and continuing noncompliance with pretreatment standards. Inspect and sample the effluent from each Significant Industrial User at least once a year. Evaluate, at least once every two years, whether each such Significant Industrial User needs a plan to control slug discharges. For purposes of this subsection, a slug discharge is any discharge of a non-routine, episodic nature, including but not limited to an accidental spill or a non-customary batch discharge. The results of such activities shall be available to the Approval Authority upon request. If the POTW decides that a slug control plan is needed, the plan shall contain, at a minimum, the following elements:
 - (A) Description of discharge practices, including non-routine batch discharges;
 - (B) Description of stored chemicals;
 - (C) Procedures for immediately notifying the POTW of slug discharges, including any discharge that would violate a prohibition under 40 CFR 403.5(b), with procedures for follow-up written notification within five days;
 - (D) If necessary, procedures to prevent adverse impact from accidental spills, including inspection and maintenance of storage areas, handling and transfer of materials, loading and unloading operations, control of plant site run-off, worker training, building of containment structures or equipment, measures for containing toxic organic pollutants (including solvents), and/or measures and equipment for emergency response;
- (vi) Investigate instances of noncompliance with Pretreatment Standards and Requirements, as indicated in the reports and notices required under § 403.12, or indicated by analysis, inspection, and surveillance activities described in paragraph (f)(2)(v) of this section. Sample taking and analysis and the collection of other information shall be performed with sufficient care to produce evidence admissible in enforcement proceedings or in judicial actions; and
- (vii) Comply with the public participation requirements of 40 CFR part 25 in the enforcement of national pretreatment standards. These procedures shall include provision for at least annual public notification, in the largest daily newspaper published in the municipality in which the POTW is located, of industrial users which, at any time during the previous twelve months, were in significant noncompliance with applicable pretreatment requirements. For the purposes of this provision, an industrial user is in significant noncompliance if its violation meets one or more of the following criteria:
 - (A) Chronic violations of wastewater discharge limits, defined here as those in which sixty-six percent or more of all of the measurements taken during a six-month period exceed (by any magnitude) the daily maximum limit or the average limit for the same pollutant parameter;
 - (B) Technical Review Criteria (TRC) violations, defined here as those in which thirty-three percent or more of all of the measurements for each pollutant parameter taken during a six-month period equal or exceed the product of the daily maximum limit or the average limit

multiplied by the applicable TRC (TRC=1.4 for BOD, TSS, fats, oil, and grease, and 1.2 for all other pollutants except pH).

(C) Any other violation of a pretreatment effluent limit (daily maximum or longer-term average) that the Control Authority determines has caused, alone or in combination with other discharges, interference or pass through (including endangering the health of POTW personnel or the general public);

(D) Any discharge of a pollutant that has caused imminent endangerment to human health, welfare or to the environment or has resulted in the POTW's exercise of its emergency authority under paragraph (f)(1)(vi)(B) of this section to halt or prevent such a discharge;

(E) Failure to meet, within 90 days after the schedule date, a compliance schedule milestone contained in a local control mechanism or enforcement order for starting construction, completing construction, or attaining final compliance;

(F) Failure to provide, within 30 days after the due date, required reports such as baseline monitoring reports, 90-day compliance reports, periodic self-monitoring reports, and reports on compliance with compliance schedules;

(G) Failure to accurately report noncompliance;

(H) Any other violation or group of violations which the Control Authority determines will adversely affect the operation or implementation of the local pretreatment program.

(3) Funding. The POTW shall have sufficient resources and qualified personnel to carry out the authorities and procedures described in paragraphs (f) (1) and (2) of this section. In some limited circumstances, funding and personnel may be delayed where (i) the POTW has adequate legal authority and procedures to carry out the Pretreatment Program requirements described in this section, and (ii) a limited aspect of the Program does not need to be implemented immediately (see § 403.9(b)).

(4) Local limits. The POTW shall develop local limits as required in § 403.5(c)(1), or demonstrate that they are not necessary.

(5) The POTW shall develop and implement an enforcement response plan. This plan shall contain detailed procedures indicating how a POTW will investigate and respond to instances of industrial user noncompliance. The plan shall, at a minimum:

(i) Describe how the POTW will investigate instances of noncompliance;

(ii) Describe the types of escalating enforcement responses the POTW will take in response to all anticipated types of industrial user violations and the time periods within which responses will take place;

(iii) Identify (by title) the official(s) responsible for each type of response;

(iv) Adequately reflect the POTW's primary responsibility to enforce all applicable pretreatment requirements and standards, as detailed in 40 CFR 403.8 (f)(1) and (f)(2).

(6) The POTW shall prepare and maintain a list of its industrial users meeting the criteria in § 403.3(u)(1). The list shall identify the criteria in § 403.3(u)(1) applicable to each industrial user and, for industrial users meeting the criteria in § 403.3(u)(ii), shall also indicate whether the POTW has made a determination pursuant to § 403.3(u)(2) that such industrial user should not be considered a significant industrial user. The initial list shall be submitted to the Approval Authority pursuant to § 403.9 as a non-substantial modification pursuant to § 403.18(d). Modifications to the list shall be submitted to the Approval Authority pursuant to § 403.12(i)(1).

Source

[46 FR 9439, Jan. 28, 1981, as amended at 49 FR 31224, Aug. 3, 1984; 51 FR 20429, 20430, June 4, 1986; 51 FR 23759, July 1, 1986; 53 FR 40612, Oct. 17, 1988; 55 FR 30129, July 24, 1990; 58 FR 18017, Apr. 7, 1993; 60 FR 33932, June 29, 1995; 62 FR 38406, 38414, July 17, 1997]

Notes

[EFFECTIVE DATE NOTE: 62 FR 38406, 38414, July 17, 1997, revised paragraphs (c) and (f)(6), effective Aug. 18, 1997.]

§ 403.9 POTW pretreatment programs and/r authorization to revise pretreatment standards: Submission for approval.

(a) Who approves Program. A POTW requesting approval of a POTW Pretreatment Program shall develop a program description which includes the information set forth in paragraphs (b)(1) through (4) of this section. This description shall be submitted to the Approval Authority which will make a determination on the request for program approval in accordance with the procedures described in § 403.11.

(b) Contents of POTW program submission. The program description must contain the following information:

(1) A statement from the City Solicitor or a city official acting in a comparable capacity (or the attorney for those POTWs which have independent legal counsel) that the POTW has authority adequate to carry out the programs described in § 403.8. This statement shall:

(i) Identify the provision of the legal authority under § 403.8(f)(1) which provides the basis for each procedure under § 403.8(f)(2);

(ii) Identify the manner in which the POTW will implement the program requirements set forth in § 403.8, including the means by which Pretreatment Standards will be applied to individual Industrial Users (e.g., by order, permit, ordinance, etc.); and,

(iii) Identify how the POTW intends to ensure compliance with Pretreatment Standards and Requirements, and to enforce them in the event of noncompliance by Industrial Users;

(2) A copy of any statutes, ordinances, regulations, agreements, or other authorities relied upon by the POTW for its administration of the Program. This Submission shall include a statement reflecting the endorsement or approval of the local boards or bodies responsible for supervising and/or funding the POTW Pretreatment Program if approved;

(3) A brief description (including organization charts) of the POTW organization which will administer the Pretreatment Program. If more than one agency is responsible for administration of the Program the responsible agencies should be identified, their respective responsibilities delineated, and their procedures for coordination set forth; and

(4) A description of the funding levels and full- and part-time manpower available to implement the Program;

(c) Conditional POTW program approval. The POTW may request conditional approval of the Pretreatment Program pending the acquisition of funding and personnel for certain elements of the Program. The request for conditional approval must meet the requirements set forth in paragraph (b) of this section except that the requirements of paragraph (b) of this section, may be relaxed if the Submission demonstrates that:

(1) A limited aspect of the Program does not need to be implemented immediately;

(2) The POTW had adequate legal authority and procedures to carry out those aspects of the Program which will not be implemented immediately; and

(3) Funding and personnel for the Program aspects to be implemented at a later date will be available when needed. The POTW will describe in the Submission the mechanism by which this funding will be acquired. Upon receipt of a request for conditional approval, the Approval Authority will establish a fixed date for the acquisition of the needed funding and personnel. If funding is not acquired by this date, the conditional approval of the POTW Pretreatment Program and any removal allowances granted to the POTW, may be modified or withdrawn.

(d) Content of removal allowance submission. The request for authority to revise categorical Pretreatment Standards must contain the information required in § 403.7(d).

(e) Approval authority action. Any POTW requesting POTW Pretreatment Program approval shall submit to the Approval Authority three copies of the Submission described in paragraph (b), and if appropriate, (d) of this section. Within 60 days after receiving the Submission, the Approval Authority shall make a preliminary determination of whether the Submission meets the requirements of paragraph (b) and, if appropriate, (d) of this section. If the Approval Authority

makes the preliminary determination that the Submission meets these requirements, the Approval Authority shall:

(1) Notify the POTW that the Submission has been received and is under review; and

(2) Commence the public notice and evaluation activities set forth in § 403.11.

(f) Notification where submission is defective. If, after review of the Submission as provided for in paragraph (e) of this section, the Approval Authority determines that the Submission does not comply with the requirements of paragraph (b) or (c) of this section, and, if appropriate, paragraph (d), of this section, the Approval Authority shall provide notice in writing to the applying POTW and each person who has requested individual notice. This notification shall identify any defects in the Submission and advise the POTW and each person who has requested individual notice of the means by which the POTW can comply with the applicable requirements of paragraphs (b), (c) of this section, and, if appropriate, paragraph (d) of this section.

(g) Consistency with water quality management plans. (1) In order to be approved the POTW Pretreatment Program shall be consistent with any approved water quality management plan developed in accordance with 40 CFR parts 130, 131, as revised, where such 208 plan includes Management Agency designations and addresses pretreatment in a manner consistent with 40 CFR part 403. In order to assure such consistency the Approval Authority shall solicit the review and comment of the appropriate 208 Planning Agency during the public comment period provided for in § 403.11(b)(1)(ii) prior to approval or disapproval of the Program.

(2) Where no 208 plan has been approved or where a plan has been approved but lacks Management Agency designations and/or does not address pretreatment in a manner consistent with this regulation, the Approval Authority shall nevertheless solicit the review and comment of the appropriate 208 planning agency.

(Information collection requirements are approved by the Office of Management and Budget under control number 2040-0009)

Source

[53 FR 9439, Jan. 28, 1981, as amended at 53 FR 40612, Oct. 17, 1988; Apr. 7, 1993]

§ 403.10 Development and submission of NPDES State pretreatment programs.

(a) Approval of State Programs. No State NPDES program shall be approved under section 402 of the Act after the effective date of these regulations unless it is determined to meet the requirements of paragraph (f) of this section. Notwithstanding any other provision of this regulation, a State will be required to act upon those authorities which it currently possesses before the approval of a State Pretreatment Program.

(b) [Removed and reserved. See 60 FR 33932, June 29, 1995.]

(c) Failure to request approval. Failure of an NPDES State with a permit program approved under section 402 of the Act prior to December 27, 1977, to seek approval of a State Pretreatment Program and failure of an approved State to administer its State Pretreatment Program in accordance with the requirements of this section constitutes grounds for withdrawal of NPDES program approval under section 402(c)(3) of the Act.

(d) [Removed and reserved. See 60 FR 33932, June 29, 1995.]

This permit shall be modified, or alternatively, revoked and reissued, by September 27, 1979 (or September 27, 1980, as appropriate) to incorporate an approved POTW Pretreatment Program or a compliance schedule for the development of a POTW Pretreatment Program as required under section 402(b)(8) of the Clean Water Act and implementing regulations or by the requirements of the approved State Pretreatment Program, as appropriate.

(2) All Permits subject to the requirements of paragraph (d)(1) of this section which do not contain the modification clause referred to in that paragraph will be subject to objection by EPA under section 402(d) of the Act as being outside the guidelines and requirements of the Act.

(3) Permits issued by an NPDES State after the Submission deadline for State Pretreatment Program approval (set forth in paragraph (b) of this section) shall contain conditions of an approved Pretreatment Program or a compliance schedule for developing such a program in accordance with §§ 403.8 (b) and (d) and 403.12(k).

(e) State Program in lieu of POTW Program. Notwithstanding the provision of § 403.8(a), a State with an approved Pretreatment Program may assume responsibility for implementing the POTW Pretreatment Program requirements set forth in § 403.8(f) in lieu of requiring the POTW to develop a Pretreatment Program. However, this does not preclude POTW's from independently developing Pretreatment Programs.

(f) State Pretreatment Program requirements. In order to be approved, a request for State Pretreatment Program Approval must demonstrate that the State Pretreatment Program has the following elements:

(1) Legal authority. The Attorney General's Statement submitted in accordance with paragraph (g)(1)(i) of this section shall certify that the Director has authority under State law to operate and enforce the State Pretreatment Program to the extent required by this part and by 40 CFR 123.27. At a minimum, the Director shall have the authority to:

(i) Incorporate POTW Pretreatment Program conditions into permits issued to POTW's; require compliance by POTW's with these incorporated permit conditions; and require compliance by Industrial Users with Pretreatment Standards;

(ii) Ensure continuing compliance by POTW's with pretreatment conditions incorporated into the POTW Permit through review of monitoring reports submitted to the Director by the POTW in accordance with § 403.12 and ensure continuing compliance by Industrial Users with Pretreatment Standards through the review of self-monitoring reports submitted to the POTW or to the Director by the Industrial Users in accordance with § 403.12;

(iii) Carry out inspection, surveillance and monitoring procedures which will determine, independent of information supplied by the POTW, compliance or noncompliance by the OTW with pretreatment conditions incorporated into the POTW Permit; and carry out inspection, surveillance and monitoring procedures which will determine, independent of information supplied by the Industrial User, whether the Industrial User is in compliance with Pretreatment Standards;

(iv) Seek civil and criminal penalties, and injunctive relief, for noncompliance by the POTW with pretreatment conditions incorporated into the POTW Permit and for noncompliance with Pretreatment Standards by Industrial Users as set forth in § 403.8(f)(1)(vi). The Director shall have authority to seek judicial relief for noncompliance by Industrial Users even when the POTW has acted to seek such relief (e.g., if the POTW has sought a penalty which the Director finds to be insufficient);

(v) Approve and deny requests for approval of POTW Pretreatment Programs submitted by a POTW to the Director;

(vi) Deny and recommend approval of (but not approve) requests for Fundamentally Different Factors variances submitted by Industrial Users in accordance with the criteria and procedures set forth in § 403.13; and

(vii) Approve and deny requests for authority to modify categorical Pretreatment Standards to reflect removals achieved by the POTW in accordance with the criteria and procedures set forth in §§ 403.7, 403.9 and 403.11.

(2) Procedures. The Director shall have developed procedures to carry out the requirements of sections 307 (b) and (c), and 402(b)(1), 402(b)(2), 402(b)(8), and 402(b)(9) of the Act. At a minimum, these procedures shall enable the Director to:

(i) Identify POTW's required to develop Pretreatment Programs in accordance with § 403.8(a) and notify these POTW's of the need to develop a POTW Pretreatment Program. In the absence of a POTW Pretreatment Program, the State shall have procedures to carry out the activities set forth in § 403.8(f)(2);

(ii) Provide technical and legal assistance to POTW's in developing Pretreatment Programs;

(iii) Develop compliance schedules for inclusion in POTW Permits which set forth the shortest reasonable time schedule for the completion of tasks needed to implement a POTW Pretreatment Program. The final compliance date in these schedules shall be no later than July 1, 1983;

(iv) Sample and analyze:

(A) Influent and effluent of the POTW to identify, independent of information supplied by the POTW, compliance or noncompliance with pollutant removal levels set forth in the POTW permit (see § 403.7); and

(B) The contents of sludge from the POTW and methods of sludge disposal and use to identify, independent of information supplied by the POTW, compliance or noncompliance with requirements applicable to the selected method of sludge management;

(v) Investigate evidence of violations of pretreatment conditions set forth in the POTW Permit by taking samples and acquiring other information as needed. This data acquisition shall be performed with sufficient care as to produce evidence admissible in an enforcement proceeding or in court;

(vi) Review and approve requests for approval of POTW Pretreatment Programs and authority to modify categorical Pretreatment Standards submitted by a POTW to the Director; and

(vii) Consider requests for Fundamentally Different Factors variances submitted by Industrial Users in accordance with the criteria and procedures set forth in § 403.13.

(3) Funding. The Director shall assure that funding and qualified personnel are available to carry out the authorities and procedures described in paragraphs (f)(1) and (2) of this section.

(g) Content of State Pretreatment Program submission. The request for State Pretreatment Program approval will consist of:

(1)(i) A statement from the State Attorney General (or the Attorney for those State agencies which have independent legal counsel) that the laws of the State provide adequate authority to implement the requirements of this part. The authorities cited by the Attorney General in this statement shall be in the form of lawfully adopted State statutes or regulations which shall be effective by the time of approval of the State Pretreatment Program; and

(ii) Copies of all State statutes and regulations cited in the above statement;

(iii) States with approved Pretreatment Programs shall establish Pretreatment regulations by November 16, 1989, unless the State would be required to enact or amend statutory provision, in which case, such regulations must be established by November 16, 1990.

(2) A description of the funding levels and full- and part-time personnel available to implement the program; and

(3) Any modifications or additions to the Memorandum of Agreement (required by 40 CFR 123.24) which may be necessary for EPA and the State to implement the requirements of this part.

(h) EPA Action. Any approved NPDES State requesting State Pretreatment Program approval shall submit to the Regional Administrator three copies of the Submission described in paragraph (g) of this section. Upon a preliminary determination that the Submission meets the requirements of paragraph (g) the Regional Administrator shall:

(1) Notify the Director that the Submission has been received and is under review; and

(2) Commence the program revision process set out in 40 CFR 123.62. For purposes of that section all requests for approval of State Pretreatment Programs shall be deemed substantial program modifications. A comment period of at least 30 days and the opportunity for a hearing shall be afforded the public on all such proposed program revisions.

(i) Notification where submission is defective. If, after review of the Submission as provided for in paragraph (h) of this section, EPA determines that the Submission does not comply with the requirements of paragraph (f) or (g) of this section EPA shall so notify the applying NPDES State in writing. This notification shall identify any defects in the Submission and advise the NPDES State of the means by which it can comply with the requirements of this part.

(Information collection requirements are approved by the Office of Management and Budget under control number 2040-0009)

Source

[46 FR 9439, Jan. 28, 1981, as amended at 51 FR 20429, June 4, 1986; 53 FR 40612, Oct. 17, 1988; 55 FR 30131, July 24, 1990; 58 FR 18017, Apr. 7, 1993; 60 FR 33932, June 29, 1995]

§ 403.11 Approval procedures for POTW pretreatment programs and POTW granting of removal credits.

Text

The following procedures shall be adopted in approving or denying requests for approval of POTW Pretreatment Programs and applications for removal credit authorization:

(a) Deadline for review of submission. The Approval Authority shall have 90 days from the date of public notice of any Submission complying with the requirements of § 403.9(b) and, where removal credit authorization is sought with §§ 403.7(e) and 403.9(d), to review the Submission. The Approval Authority shall review the Submission to determine compliance with the requirements of § 403.8 (b) and (f), and, where removal credit authorization is sought, with § 403.7. The Approval Authority may have up to an additional 90 days to complete the evaluation of the Submission if the public comment period provided for in paragraph (b)(1)(ii) of this section is extended beyond 30 days or if a public hearing is held as provided for in paragraph (b)(2) of this section. In no event, however, shall the time for evaluation of the Submission exceed a total of 180 days from the date of public notice of a Submission meeting the requirements of § 403.9(b) and, in the case of a removal credit application, §§ 403.7(e) and 403.9(b).

(b) Public notice and opportunity for hearing. Upon receipt of a Submission the Approval Authority shall commence its review. Within 20 work days after making a determination that a Submission meets the requirements of § 403.9(b) and, where removal allowance approval is sought, §§ 403.7(d) and 403.9(d), the Approval Authority shall:

(1) Issue a public notice of request for approval of the Submission;

(i) This public notice shall be circulated in a manner designed to inform interested and potentially interested persons of the Submission. Procedures for the circulation of public notice shall include:

(A) Mailing notices of the request for approval of the Submission to designated 208 planning agencies, Federal and State fish, shellfish and wildfish resource agencies (unless such agencies have asked not to be sent the notices); and to any other person or group who has requested individual notice, including those on appropriate mailing lists; and

(B) Publication of a notice of request for approval of the Submission in a newspaper(s) of general circulation within the jurisdiction(s) served by the POTW that meaningful public notice.

(ii) The public notice shall provide a period of not less than 30 days following the date of the public notice during which time interested persons may submit their written views on the Submission.

(iii) All written comments submitted during the 30 day comment period shall be retained by the Approval Authority and considered in the decision on whether or not to approve the Submission. The period for comment may be extended at the discretion of the Approval Authority; and

(2) Provide an opportunity for the applicant, any affected State, any interested State or Federal agency, person or group of persons to request a public hearing with respect to the Submission.

(i) This request for public hearing shall be filed within the 30 day (or extended) comment period described in paragraph (b)(1)(ii) of this section and shall indicate the interest of the person filing such request and the reasons why a hearing is warranted.

(ii) The Approval Authority shall hold a hearing if the POTW so requests. In addition, a hearing will be held if there is a significant public interest in issues relating to whether or not the Submission should be approved. Instances of doubt should be resolved in favor of holding the hearing.

(iii) Public notice of a hearing to consider a Submission and sufficient to inform interested parties of the nature of the hearing and the right to participate shall be published in the same newspaper as the notice of the original request for approval of the Submission under paragraph (b)(1)(i)(B) of this section. In addition, notice of the hearing shall be sent to those persons requesting individual notice.

(c) Approval authority decision. At the end of the 30 day (or extended) comment period and within the 90 day (or extended) period provided for in paragraph (a) of this section, the Approval Authority shall approve or deny the Submission based upon the evaluation in paragraph (a) of this section and taking into consideration comments submitted during the comment period and the record of the public hearing, if held. Where the Approval Authority makes a determination to deny the request, the Approval Authority shall so notify the POTW and each person who has requested individual notice. This notification shall include suggested modifications and the Approval Authority may allow the requestor additional time to bring the Submission into compliance with applicable requirements.

(d) EPA objection to Director's decision. No POTW pretreatment program or authorization to grant removal allowances shall be approved by the Director if following the 30 day (or extended) evaluation period provided for in paragraph (b)(1)(ii) of this section and any hearing held pursuant to paragraph (b)(2) of this section the Regional Administrator sets forth in writing objections to the approval of such Submission and the reasons for such objections. A copy of the Regional Administrator's objections shall be provided to the applicant, and each person who has requested individual notice. The Regional Administrator shall provide an opportunity for written comments and may convene a public hearing on his or her objections. Unless retracted, the Regional Administrator's objections shall constitute a final ruling to deny approval of a POTW pretreatment program or authorization to grant removal allowances 90 days after the date the objections are issued.

(e) Notice of decision. The Approval Authority shall notify those persons who submitted comments and participated in the public hearing, if held, of the approval or disapproval of the Submission. In addition, the Approval Authority shall cause to be published a notice of approval or disapproval in the same newspapers as the original notice of request for approval of the Submission was published. The Approval Authority shall identify in any notice of POTW Pretreatment Program approval any authorization to modify categorical Pretreatment Standards which the POTW may make, in accordance with § 403.7, for removal of pollutants subject to Pretreatment Standards.

(f) Public access to submission. The Approval Authority shall ensure that the Submission and any comments upon such Submission are available to the public for inspection and copying.

Source

[46 FR 9439, Jan. 28, 1981, as amended at 49 FR 31224, Aug. 3, 1984; 51 FR 20429, June 4, 1986; 53 FR 40613, Oct. 17, 1988; 62 FR 38406, 38414, July 17, 1997]

Notes

[EFFECTIVE DATE NOTE: 62 FR 38406, 38414, July 17, 1997, revised paragraphs (b)(1)(i)(A) and (B), effective Aug. 18, 1997.]

§ 403.12 Reporting requirements for POTW's and industrial users.

(a) Definition. The term Control Authority as it is used in this section refers to: (1) The POTW if the POTW's Submission for its pretreatment program (§ 403.3(t)(1)) has been approved in accordance with the requirements of § 403.11; or (2) the Approval Authority if the Submission has not been approved.

(b) Reporting requirements for industrial users upon effective date of categorical pretreatment standard -- baseline report. Within 180 days after the effective date of a categorical Pretreatment Standard, or 180 days after the final administrative decision made upon a

category determination submission under § 1A403.6(a)(4), whichever is later, existing Industrial Users subject to such categorical Pretreatment Standards and currently discharging to or scheduled to discharge to a POTW shall be required to submit to the Control Authority a report which contains the information listed in paragraphs (b)(1)-(7) of this section. At least 90 days prior to commencement of discharge, New Sources, and sources that become Industrial Users subsequent to the promulgation of an applicable categorical Standard, shall be required to submit to the Control Authority a report which contains the information listed in paragraphs (b)(1)-(5) of this section. New sources shall also be required to include in this report information on the method of pretreatment the source intends to use to meet applicable pretreatment standards. New Sources shall give estimates of the information requested in paragraphs (b) (4) and (5) of this section:

(1) Identifying information. The User shall submit the name and address of the facility including the name of the operator and owners;

(2) Permits. The User shall submit a list of any environmental control permits held by or for the facility;

(3) Description of operations. The User shall submit a brief description of the nature, average rate of production, and Standard Industrial Classification of the operation(s) carried out by such Industrial User. This description should include a schematic process diagram which indicates points of Discharge to the POTW from the regulated processes.

(4) Flow measurement. The User shall submit information showing the measured average daily and maximum daily flow, in gallons per day, to the POTW from each of the following:

(i) Regulated process streams; and

(ii) Other streams as necessary to allow use of the combined wastestream formula of § 403.6(e). (See paragraph (b)(5)(v) of this section.)

The Control Authority may allow for verifiable estimates of these flows where justified by cost or feasibility considerations.

(5) Measurement of pollutants. (i) The user shall identify the Pretreatment Standards applicable to each regulated process;

(ii) In addition, the User shall submit the results of sampling and analysis identifying the nature and concentration (or mass, where required by the Standard or Control Authority) of regulated pollutants in the Discharge from each regulated process. Both daily maximum and average concentration (or mass, where required) shall be reported. The sample shall be representative of daily operations;

(iii) A minimum of four (4) grab samples must be used for pH, cyanide, total phenols, oil and grease, sulfide, and volatile organics. For all other pollutants, 24-hour composite samples must be obtained through flow-proportional composite sampling techniques where feasible. The Control Authority may waive flow-proportional composite sampling for any Industrial User that demonstrates that flow-proportional sampling is infeasible. In such cases, samples may be obtained through time-proportional composite sampling techniques or through a minimum of four (4) grab samples where the User demonstrates that this will provide a representative sample of the effluent being discharged.

(iv) The User shall take a minimum of one representative sample to compile that data necessary to comply with the requirements of this paragraph.

(v) Samples should be taken immediately downstream from pretreatment facilities if such exist or immediately downstream from the regulated process if no pretreatment exists. If other wastewaters are mixed with the regulated wastewater prior to pretreatment the User should measure the flows and concentrations necessary to allow use of the combined wastestream formula of § 403.6(e) in order to evaluate compliance with the Pretreatment Standards. Where an alternate concentration or mass limit has been calculated in accordance with § 403.6(e) this adjusted limit along with supporting data shall be submitted to the Control Authority;

(vi) Sampling and analysis shall be performed in accordance with the techniques prescribed in 40 CFR part 136 and amendments thereto. Where 40 CFR part 136 does not contain sampling

or analytical techniques for the pollutant in question, or where the Administrator determines that the part 136 sampling and analytical techniques are inappropriate for the pollutant in question, sampling and analysis shall be performed by using validated analytical methods or any other applicable sampling and analytical procedures, including procedures suggested by the POTW or other parties, approved by the Administrator;

(vii) The Control Authority may allow the submission of a baseline report which utilizes only historical data so long as the data provides information sufficient to determine the need for industrial pretreatment measures;

(viii) The baseline report shall indicate the time, date and place, of sampling, and methods of analysis, and shall certify that such sampling and analysis is representative of normal work cycles and expected pollutant Discharges to the POTW;

(6) Certification. A statement, reviewed by an authorized representative of the Industrial User (as defined in paragraph (k) of this section) and certified to by a qualified professional, indicating whether Pretreatment Standards are being met on a consistent basis, and, if not, whether additional operation and maintenance (O and M) and/or additional pretreatment is required for the Industrial User to meet the Pretreatment Standards and Requirements; and

(7) Compliance schedule. If additional pretreatment and/or O and M will be required to meet the Pretreatment Standards; the shortest schedule by which the Industrial User will provide such additional pretreatment and/or O and M. The completion date in this schedule shall not be later than the compliance date established for the applicable Pretreatment Standard.

(i) Where the Industrial User's categorical Pretreatment Standard has been modified by a removal allowance (§ 403.7), the combined wastestream formula (§ 1A403.6(e)), and/or a Fundamentally Different Factors variance (§ 403.13) at the time the User submits the report required by paragraph (b) of this section, the information required by paragraphs (b)(6) and (7) of this section shall pertain to the modified limits.

(ii) If the categorical Pretreatment Standard is modified by a removal allowance (§ 403.7), the combined wastestream formula (§ 403.6(e)), and/or a Fundamentally Different Factors variance (§ 403.13) after the User submits the report required by paragraph (b) of this section, any necessary amendments to the information requested by paragraphs (b)(6) and (7) of this section shall be submitted by the User to the Control Authority within 60 days after the modified limit is approved.

(c) Compliance schedule for meeting categorical Pretreatment Standards. T1The following conditions shall apply to the schedule required by paragraph (b)(7) of this section:

(1) The schedule shall contain increments of progress in the form of dates for the commencement and completion of major events leading to the construction and operation of additional pretreatment required for the Industrial User to meet the applicable categorical Pretreatment Standards (e.g., hiring an engineer, completing preliminary plans, completing final plans, executing contract for major components, commencing construction, completing construction, etc.).

(2) No increment referred to in paragraph (c)(1) of this section shall exceed 9 months.

(3) Not later than 14 days following each date in the schedule and the final date for compliance, the Industrial User shall submit a progress report to the Control Authority including, at a minimum, whether or not it complied with the increment of progress to be met on such date and, if not, the date on which it expects to comply with this increment of progress, the reason for delay, and the steps being taken by the Industrial User to return the construction to the schedule established. In no event shall more than 9 months elapse between such progress reports to the Control Authority.

(d) Report on compliance with categorical pretreatment standard deadline. Within 90 days following the date for final compliance with applicable categorical Pretreatment Standards or in the case of a New Source following commencement of the introduction of wastewater into the POTW, any Industrial User subject to Pretreatment Standards and Requirements shall submit to the Control Authority a report containing the information described in paragraphs (b) (4)-(6) of

this section. For Industrial Users subject to equivalent mass or concentration limits established by the Control Authority in accordance with the procedures in § 403.6(c), this report shall contain a reasonable measure of the User's long term production rate. For all other Industrial Users subject to categorical Pretreatment Standards expressed in terms of allowable pollutant discharge per unit of production (or other measure of operation), this report shall include the User's actual production during the appropriate sampling period.

(e) Periodic reports on continued compliance. (1) Any Industrial User subject to a categorical Pretreatment Standard, after the compliance date of such Pretreatment Standard, or, in the case of a New Source, after commencement of the discharge into the POTW, shall submit to the Control Authority during the months of June and December, unless required more frequently in the Pretreatment Standard or by the Control Authority or the Approval Authority, a report indicating the nature and concentration of pollutants in the effluent which are limited by such categorical Pretreatment Standards. In addition, this report shall include a record of measured or estimated average and maximum daily flows for the reporting period for the Discharge reported in paragraph (b)(4) of this section except that the Control Authority may require more detailed reporting of flows. At the discretion of the Control Authority and in consideration of such factors as local high or low flow rates, holidays, budget cycles, etc., the Control Authority may agree to alter the months during which the above reports are to be submitted.

(2) Where the Control Authority has imposed mass limitations on Industrial Users as provided for by § 403.6(d), the report required by paragraph (e)(1) of this section shall indicate the mass of pollutants regulated by Pretreatment Standards in the Discharge from the Industrial User.

(3) For Industrial Users subject to equivalent mass or concentration limits established by the Control Authority in accordance with the procedures in § 403.6(c), the report required by paragraph (e)(1) shall contain a reasonable measure of the User's long term production rate. For all other Industrial Users subject to categorical Pretreatment Standards expressed only in terms of allowable pollutant discharge per unit of production (or other measure of operation), the report required by paragraph (e)(1) shall include the User's actual average production rate for the reporting period.

(f) Notice of potential problems, including slug loading. All categorical and non-categorical Industrial Users shall notify the POTW immediately of all discharges that could cause problems to the POTW, including any slug loadings, as defined by § 403.5(b), by the Industrial User.

(g) Monitoring and analysis to demonstrate continued compliance. (1) The reports required in paragraphs (b), (d), and (e) of this section shall contain the results of sampling and an analysis of the Discharge, including the flow and the nature and concentration, or production and mass where requested by the Control Authority, of pollutants contained therein which are limited by the applicable Pretreatment Standards. This sampling and analysis may be performed by the Control Authority in lieu of the Industrial User. Where the POTW performs the required sampling and analysis in lieu of the Industrial User, the User will not be required to submit the compliance certification required under §§ 403.12(b) (6) and 403.12(d). In addition, where the POTW itself collects all the information required for the report, including flow data, the Industrial User will not be required to submit the report.

(2) If sampling performed by an Industrial User indicates a violation, the user shall notify the Control Authority within 24 hours of becoming aware of the violation. The User shall also repeat the sampling and analysis and submit the results of the repeat analysis to the Control Authority within 30 days after becoming aware of the violation, except the Industrial User is not required to resample if:

(i) The Control Authority performs sampling at the Industrial User at a frequency of at least once per month, or

(ii) The Control Authority performs sampling at the User between the time when the User performs its initial sampling and the time when the User receives the results of this sampling.

(3) The reports required in paragraph (e) of this section shall be based upon data obtained through appropriate sampling and analysis performed during the period covered by the report,

which data is representative of conditions occurring during the reporting period. The Control Authority shall require that frequency of monitoring necessary to assess and assure compliance by Industrial Users with applicable Pretreatment Standards and Requirements.

(4) All analyses shall be performed in accordance with procedures established by the Administrator pursuant to section 304(h) of the Act and contained in 40 CFR part 136 and amendments thereto or with any other test procedures approved by the Administrator. (See, §§ 136.4 and 136.5.) Sampling shall be performed in accordance with the techniques approved by the Administrator. Where 40 CFR part 136 does not include sampling or analytical techniques for the pollutants in question, or where the Administrator determines that the part 136 sampling and analytical techniques are inappropriate for the pollutant in question, sampling and analyses shall be performed using validated analytical methods or any other sampling and analytical procedures, including procedures suggested by the POTW or other parties, approved by the Administrator.

(5) If an Industrial User subject to the reporting requirement in paragraph (e) of this section monitors any pollutant more frequently than required by the Control Authority, using the procedures prescribed in paragraph (g)(4) of this section, the results of this monitoring shall be included in the report.

(h) Reporting requirements for Industrial Users not subject to categorical Pretreatment Standards. The Control Authority shall require appropriate reporting from those Industrial Users with discharges that are not subject to categorical Pretreatment Standards. Significant Noncategorical Industrial Users shall submit to the Control Authority at least once every six months (on dates specified by the Control Authority) a description of the nature, concentration, and flow of the pollutants required to be reported by the Control Authority. These reports shall be based on sampling and analysis performed in the period covered by the report, and performed in accordance with the techniques described in 40 CFR part 136 and amendments thereto. Where 40 CFR part 136 does not contain sampling or analytical techniques for the pollutant in question, or where the Administrator determines that the part 136 sampling and analytical techniques are inappropriate for the pollutant in question, sampling and analysis shall be performed by using validated analytical methods or any other applicable sampling and analytical procedures, including procedures suggested by the POTW or other persons, approved by the Administrator. This sampling and analysis may be performed by the Control Authority in lieu of the significant noncategorical industrial user. Where the POTW itself collects all the information required for the report, the noncategorical significant industrial user will not be required to submit the report.

(i) Annual POTW reports. POTWs with approved Pretreatment Programs shall provide the Approval Authority with a report that briefly describes the POTW's program activities, including activities of all participating agencies, if more than one jurisdiction is involved in the local program. The report required by this section shall be submitted no later than one year after approval of the POTW's Pretreatment Program, and at least annually thereafter, and shall include, at a minimum, the following:

(1) An updated list of the POTW's Industrial Users, including their names and addresses, or a list of deletions and additions keyed to a previously submitted list. The POTW shall provide a brief explanation of each deletion. This list shall identify which Industrial Users are subject to categorical pretreatment Standards and specify which Standards are applicable to each Industrial User. The list shall indicate which Industrial Users are subject to local standards that are more stringent than the categorical Pretreatment Standards. The POTW shall also list the Industrial Users that are subject only to local Requirements.

(2) A summary of the status of Industrial User compliance over the reporting period;

(3) A summary of compliance and enforcement activities (including inspections) conducted by the POTW during the reporting period;

(4) A summary of changes to the POTW's pretreatment program that have not been previously reported to the Approval Authority; and

(5) Any other relevant information requested by the Approval Authority.

(j) Notification of changed discharge. All Industrial Users shall promptly notify the POTW in advance of any substantial change in the volume or character of pollutants in their discharge, including the listed or characteristic hazardous wastes for which the Industrial User has submitted initial notification under 40 CFR 403.12(p).

(k) Compliance schedule for POTW's. The following conditions and reporting requirements shall apply to the compliance schedule for development of an approvable POTW Pretreatment Program required by § 403.8.

(1) The schedule shall contain increments of progress in the form of dates for the commencement and completion of major events leading to the development and implementation of a POTW Pretreatment Program (e.g., acquiring required authorities, developing funding mechanisms, acquiring equipment);

(2) No increment referred to in paragraph (h)(1) of this section shall exceed nine months;

(3) Not later than 14 days following each date in the schedule and the final date for compliance, the POTW shall submit a progress report to the Approval Authority including, as a minimum, whether or not it complied with the increment of progress to be met on such date and, if not, the date on which it expects to comply with this increment of progress, the reason for delay, and the steps taken by the POTW to return to the schedule established. In no event shall more than nine months elapse between such progress reports to the Approval Authority.

(l) Signatory requirements for industrial user reports. The reports required by paragraphs (b), (d), and (e) of this section shall include the certification statement as set forth in § 403.6(a)(2)(ii), and shall be signed as follows:

(1) By a responsible corporate officer, if the Industrial User submitting the reports required by paragraphs (b), (d) and (e) of this section is a corporation. For the purpose of this paragraph, a responsible corporate officer means (i) a president, secretary, treasurer, or vice-president of the corporation in charge of a principal business function, or any other person who performs similar policy- or decision-making functions for the corporation, or (ii) the manager of one or more manufacturing, production, or operation facilities employing more than 250 persons or having gross annual sales or expenditures exceeding \$ 25 million (in second-quarter 1980 dollars), if authority to sign documents has been assigned or delegated to the manager in accordance with corporate procedures.

(2) By a general partner or proprietor if the Industrial User submitting the reports required by paragraphs (b), (d) and (e) of this section is a partnership or sole proprietorship respectively.

(3) By a duly authorized representative of the individual designated in paragraph (l)(1) or (l)(2) of this section if:

(i) The authorization is made in writing by the individual described in paragraph (l)(1) or (l)(2);

(ii) The authorization specifies either an individual or a position having responsibility for the overall operation of the facility from which the Industrial Discharge originates, such as the position of plant manager, operator of a well, or well field superintendent, or a position of equivalent responsibility, or having overall responsibility for environmental matters for the company; and

(iii) the written authorization is submitted to the Control Authority.

(4) If an authorization under paragraph (l)(3) of this section is no longer accurate because a different individual or position has responsibility for the overall operation of the facility, or overall responsibility for environmental matters for the company, a new authorization satisfying the requirements of paragraph (l)(3) of this section must be submitted to the Control Authority prior to or together with any reports to be signed by an authorized representative.

(m) Signatory requirements for POTW reports. Reports submitted to the Approval Authority by the POTW in accordance with paragraph (h) of this section must be signed by a principal executive officer, ranking elected official or other duly authorized employee if such employee is responsible for overall operation of the POTW.

(n) Provisions Governing Fraud and False Statements: The reports and other documents required to be submitted or maintained under this section shall be subject to:

(1) The provisions of 18 U.S.C. section 1001 relating to fraud and false statements;
(2) The provisions of sections 309(c)(4) of the Act, as amended, governing false statements, representation or certification; and

(3) The provisions of section 309(c)(6) regarding responsible corporate officers.

(o) Record-keeping requirements. (1) Any Industrial User and POTW subject to the reporting requirements established in this section shall maintain records of all information resulting from any monitoring activities required by this section. Such records shall include for all samples:

(i) The date, exact place, method, and time of sampling and the names of the person or persons taking the samples;

(ii) The dates analyses were performed;

(iii) Who performed the analyses;

(iv) The analytical techniques/methods use; and

(v) The results of such analyses.

(2) Any Industrial User or POTW subject to the reporting requirements established in this section shall be required to retain for a minimum of 3 years any records of monitoring activities and results (whether or not such monitoring activities are required by this section) and shall make such records available for inspection and copying by the Director and the Regional Administrator (and POTW in the case of an Industrial User). This period of retention shall be extended during the course of any unresolved litigation regarding the Industrial User or POTW or when requested by the Director or the Regional Administrator.

(3) Any POTW to which reports are submitted by an Industrial User pursuant to paragraphs (b), (d), (e), and (h) of this section shall retain such reports for a minimum of 3 years and shall make such reports available for inspection and copying by the Director and the Regional Administrator. This period of retention shall be extended during the course of any unresolved litigation regarding the discharge of pollutants by the Industrial User or the operation of the POTW Pretreatment Program or when requested by the Director or the Regional Administrator.

(p)(1) The Industrial User shall notify the POTW, the EPA Regional Waste Management Division Director, and State hazardous waste authorities in writing of any discharge into the POTW of a substance, which, if otherwise disposed of, would be a hazardous waste under 40 CFR part 261. Such notification must include the name of the hazardous waste as set forth in 40 CFR part 261, the EPA hazardous waste number, and the type of discharge (continuous, batch, or other). If the Industrial User discharges more than 100 kilograms of such waste per calendar month to the POTW, the notification shall also contain the following information to the extent such information is known and readily available to the Industrial User: An identification of the hazardous constituents contained in the wastes, an estimation of the mass and concentration of such constituents in the wastestream discharged during that calendar month, and an estimation of the mass of constituents in the wastestream expected to be discharged during the following twelve months. All notifications must take place within 180 days of the effective date of this rule. Industrial users who commence discharging after the effective date of this rule shall provide the notification no later than 180 days after the discharge of the listed or characteristic hazardous waste. Any notification under this paragraph need be submitted only once for each hazardous waste discharged. However, notifications of changed discharges must be submitted under 40 CFR 403.12 (j). The notification requirement in this section does not apply to pollutants already reported under the self-monitoring requirements of 40 CFR 403.12 (b), (d), and (e).

(2) Dischargers are exempt from the requirements of paragraph (p)(1) of this section during a calendar month in which they discharge no more than fifteen kilograms of hazardous wastes, unless the wastes are acute hazardous wastes as specified in 40 CFR 261.30(d) and 261.33(e). Discharge of more than fifteen kilograms of non-acute hazardous wastes in a calendar month, or of any quantity of acute hazardous wastes as specified in 40 CFR 261.30(d) and 261.33(e), requires a one-time notification.

Subsequent months during which the Industrial User discharges more than such quantities of any hazardous waste do not require additional notification.

(3) In the case of any new regulations under section 3001 of RCRA identifying additional characteristics of hazardous waste or listing any additional substance as a hazardous waste, the Industrial User must notify the POTW, the EPA Regional Waste Management Waste Division Director, and State hazardous waste authorities of the discharge of such substance within 90 days of the effective date of such regulations.

(4) In the case of any notification made under paragraph (p) of this section, the Industrial User shall certify that it has a program in place to reduce the volume and toxicity of hazardous wastes generated to the degree it has determined to be economically practical.

Source

[46 FR 9439, Jan. 28, 1981, as amended at 49 FR 31225, Aug. 3, 1984; 51 FR 20429, June 4, 1986; 53 FR 40613, Oct. 17, 1988; 55 FR 30131, July 24, 1990; 58 FR 18017, Apr. 7, 1993; 60 FR 33932, June 29, 1995; 62 FR 38406, 38414, July 17, 1997]

Notes

[EFFECTIVE DATE NOTE: 62 FR 38406, 38414, July 17, 1997, redesignated paragraph (i)(4) as paragraph (i)(5), revised paragraph (i)(3), and added a new paragraph (i)(4), effective Aug. 18, 1997.]

§ 403.13 Variances from categorical pretreatment standards for fundamentally different factors.

(a) Definition. The term Requester means an Industrial User or a POTW or other interested person seeking a variance from the limits specified in a categorical Pretreatment Standard.

(b) Purpose and scope. In establishing categorical Pretreatment Standards for existing sources, the EPA will take into account all the information it can collect, develop and solicit regarding the factors relevant to pretreatment standards under section 307(b). In some cases, information which may affect these Pretreatment Standards will not be available or, for other reasons, will not be considered during their development. As a result, it may be necessary on a case-by-case basis to adjust the limits in categorical Pretreatment Standards, making them either more or less stringent, as they apply to a certain Industrial User within an industrial category or subcategory. This will only be done if data specific to that Industrial User indicates it presents factors fundamentally different from those considered by EPA in developing the limit at issue. Any interested person believing that factors relating to an Industrial User are fundamentally different from the factors considered during development of a categorical Pretreatment Standard applicable to that User and further, that the existence of those factors justifies a different discharge limit than specified in the applicable categorical Pretreatment Standard, may request a fundamentally different factors variance under this section or such a variance request may be initiated by the EPA.

(c) Criteria -- (1) General criteria. A request for a variance based upon fundamentally different factors shall be approved only if:

(i) There is an applicable categorical Pretreatment Standard which specifically controls the pollutant for which alternative limits have been requested; and

(ii) Factors relating to the discharge controlled by the categorical Pretreatment Standard are fundamentally different from the factors considered by EPA in establishing the Standards; and

(iii) The request for a variance is made in accordance with the procedural requirements in paragraphs (g) and (h) of this section.

(2) Criteria applicable to less stringent limits. A variance request for the establishment of limits less stringent than required by the Standard shall be approved only if:

(i) The alternative limit requested is no less stringent than justified by the fundamental difference;

- (ii) The alternative limit will not result in a violation of prohibitive discharge standards prescribed by or established under § 403.5;
- (iii) The alternative limit will not result in a non-water quality environmental impact (including energy requirements) fundamentally more adverse than the impact considered during development of the Pretreatment Standards; and
- (iv) Compliance with the Standards (either by using the technologies upon which the Standards are based or by using other control alternatives) would result in either:
 - (A) A removal cost (adjusted for inflation) wholly out of proportion to the removal cost considered during development of the Standards; or
 - (B) A non-water quality environmental impact (including energy requirements) fundamentally more adverse than the impact considered during development of the Standards.
- (3) Criteria applicable to more stringent limits. A variance request for the establishment of limits more stringent than required by the Standards shall be approved only if:
 - (i) The alternative limit request is no more stringent than justified by the fundamental difference; and
 - (ii) Compliance with the alternative limit would not result in either:
 - (A) A removal cost (adjusted for inflation) wholly out of proportion to the removal cost considered during development of the Standards; or
 - (B) A non-water quality environmental impact (including energy requirements) fundamentally more adverse than the impact considered during development of the Standards.
- (d) Factors considered fundamentally different. Factors which may be considered fundamentally different are:
 - (1) The nature or quality of pollutants contained in the raw waste load of the User's process wastewater;
 - (2) The volume of the User's process wastewater and effluent discharged;
 - (3) Non-water quality environmental impact of control and treatment of the User's raw waste load;
 - (4) Energy requirements of the application of control and treatment technology;
 - (5) Age, size, land availability, and configuration as they relate to the User's equipment or facilities; processes employed; process changes; and engineering aspects of the application of control technology;
 - (6) Cost of compliance with required control technology.
- (e) Factors which will not be considered fundamentally different. A variance request or portion of such a request under this section may not be granted on any of the following grounds:
 - (1) The feasibility of installing the required waste treatment equipment within the time the Act allows;
 - (2) The assertion that the Standards cannot be achieved with the appropriate waste treatment facilities installed, if such assertion is not based on factors listed in paragraph (d) of this section;
 - (3) The User's ability to pay for the required waste treatment; or
 - (4) The impact of a Discharge on the quality of the POTW's receiving waters.
- (f) State or local law. Nothing in this section shall be construed to impair the right of any state or locality under section 510 of the Act to impose more stringent limitations than required by Federal law.
- (g) Application deadline.
 - (1) Requests for a variance and supporting information must be submitted in writing to the Director or to the Administrator (or his delegate), as appropriate.
 - (2) In order to be considered, a request for a variance must be submitted no later than 180 days after the date on which a categorical Pretreatment Standard is published in the Federal Register.
 - (3) Where the User has requested a categorical determination pursuant to § 1A403.6(a), the User may elect to await the results of the category determination before submitting a variance request under this section. Where the User so elects, he or she must submit the variance

request within 30 days after a final decision has been made on the categorical determination pursuant to § 403.6(a)(4).

(h) Contents submission. Written submissions for variance requests, whether made to the Administrator (or his delegate) or the Director, must include:

- (1) The name and address of the person making the request;
 - (2) Identification of the interest of the Requester which is affected by the categorical Pretreatment Standard for which the variance is requested;
 - (3) Identification of the POTW currently receiving the waste from the Industrial User for which alternative discharge limits are requested;
 - (4) Identification of the categorical Pretreatment Standards which are applicable to the Industrial User;
 - (5) A list of each pollutant or pollutant parameter for which an alternative discharge limit is sought;
 - (6) The alternative discharge limits proposed by the Requester for each pollutant or pollutant parameter identified in paragraph (h)(5) of this section;
 - (7) A description of the Industrial User's existing water pollution control facilities;
 - (8) A schematic flow representation of the Industrial User's water system including water supply, process wastewater systems, and points of Discharge; and
 - (9) A Statement of facts clearly establishing why the variance request should be approved, including detailed support data, documentation, and evidence necessary to fully evaluate the merits of the request, e.g., technical and economic data collected by the EPA and used in developing each pollutant discharge limit in the Pretreatment Standard.
- (i) Deficient requests. The Administrator (or his delegate) or the Director will only act on written requests for variances that contain all of the information required. Persons who have made incomplete submissions will be notified by the Administrator (or his delegate) or the Director that their requests are deficient and unless the time period is extended, will be given up to thirty days to remedy the deficiency. If the deficiency is not corrected within the time period allowed by the Administrator (or his delegate) or the Director, the request for a variance shall be denied.
- (j) Public notice. Upon receipt of a complete request, the Administrator (or his delegate) or the Director will provide notice of receipt, opportunity to review the submission, and opportunity to comment.
- (1) The public notice shall be circulated in a manner designed to inform interested and potentially interested persons of the request. Procedures for the circulation of public notice shall include mailing notices to:
 - (i) The POTW into which the Industrial User requesting the variance discharges;
 - (ii) Adjoining States whose waters may be affected; and
 - (iii) Designated 208 planning agencies, Federal and State fish, shellfish and wildlife resource agencies; and to any other person or group who has requested individual notice, including those on appropriate mailing lists.
 - (2) The public notice shall provide for a period not less than 30 days following the date of the public notice during which time interested persons may review the request and submit their written views on the request.
 - (3) Following the comment period, the Administrator (or his delegate) or the Director will make a determination on the request taking into consideration any comments received. Notice of this final decision shall be provided to the requester (and the Industrial User for which the variance is requested if different), the POTW into which the Industrial User discharges and all persons who submitted comments on the request.
- (k) Review of requests by state. (1) Where the Director finds that fundamentally different factors do not exist, he may deny the request and notify the requester (and Industrial User where they are not the same) and the POTW of the denial.

(2) Where the Director finds that fundamentally different factors do exist, he shall forward the request, with a recommendation that the request be approved, to the Administrator (or his delegate).

(l) Review of requests by EPA. (1) Where the Administrator (or his delegate) finds that fundamentally different factors do not exist, he shall deny the request for a variance and send a copy of his determination to the Director, to the POTW, and to the requester (and to the Industrial User, where they are not the same).

(2) Where the Administrator (or his delegate) finds that fundamentally different factors do exist, and that a partial or full variance is justified, he will approve the variance. In approving the variance, the Administrator (or his delegate) will:

(i) Prepare recommended alternative discharge limits for the Industrial User either more or less stringent than those prescribed by the applicable categorical Pretreatment Standard to the extent warranted by the demonstrated fundamentally different factors;

(ii) Provide the following information in his written determination:

(A) The recommended alternative discharge limits for the Industrial User concerned;

(B) The rationale for the adjustment of the Pretreatment Standard (including the reasons for recommending that the variance be granted) and an explanation of how the recommended alternative discharge limits were derived;

(C) The supporting evidence submitted to the Administrator (or his delegate); and

(D) Other information considered by the Administrator (or his delegate) in developing the recommended alternative discharge limits;

(iii) Notify the Director and the POTW of his or her determination; and

(iv) Send the information described in paragraphs (l)(2) (i) and (ii) of this section to the Requestor (and to the Industrial User where they are not the same).

(m) Request for hearing. (1) Within 30 days following the date of receipt of the notice of the decision of the Administrator's delegate on a variance request, the requester or any other interested person may submit a petition to the Regional Administrator for a hearing to reconsider or contest the decision. If such a request is submitted by a person other than the Industrial User the person shall simultaneously serve a copy of the request on the Industrial User.

(2) If the Regional Administrator declines to hold a hearing and the Regional Administrator affirms the findings of the Administrator's delegate the requester may submit a petition for a hearing to the Environmental Appeals Board (which is described in § 1.25 of this title) within 30 days of the Regional Administrator's decision.

(Information collection requirements are approved by the Office of Management and Budget under control number 2040-0009)

Source

[46 FR 9439, Jan. 28, 1981, as amended at 49 FR 5132, Feb. 10, 1984; 50 FR 38811, Sept. 25, 1985; 51 FR 16030, Apr. 30, 1986; 54 FR 258, Jan. 4, 1989; 57 FR 5347, Feb. 13, 1992; FR 18017, Apr. 7, 1993; 60 FR 33932, June 29, 1995]

§ 403.14 Confidentiality.

(a) EPA authorities. In accordance with 40 CFR part 2, any information submitted to EPA pursuant to these regulations may be claimed as confidential by the submitter. Any such claim must be asserted at the time of submission in the manner prescribed on the application form or instructions, or, in the case of other submissions, by stamping the words "confidential business information" on each page containing such information. If no claim is made at the time of submission, EPA may make the information available to the public without further notice. If a claim is asserted, the information will be treated in accordance with the procedures in 40 CFR part 2 (Public Information).

(b) Effluent data. Information and data provided to the Control Authority pursuant to this part which is effluent data shall be available to the public without restriction.

(c) State or POTW. All other information which is submitted to the State or POTW shall be available to the public at least to the extent provided by 40 CFR 2.302.

Source

46 FR 9439, Jan. 28, 1981.

§ 403.15 Netgross calculation.

Categorical Pretreatment Standards may be adjusted to reflect the presence of pollutants in the Industrial User's intake water in accordance with this section.

(a) Application. Any Industrial User wishing to obtain credit for intake pollutants must make application to the Control Authority. Upon request of the Industrial User, the applicable Standard will be calculated on a "net" basis (i.e., adjusted to reflect credit for pollutants in the intake water) if the requirements of paragraphs (b) and (c) of this section are met.

(b) Criteria. (1) The Industrial User must demonstrate that the control system it proposes or uses to meet applicable categorical Pretreatment Standards would, if properly installed and operated, meet the Standards in the absence of pollutants in the intake waters.

(2) Credit for generic pollutants such as biochemical oxygen demand (BOD), total suspended solids (TSS), and oil and grease should not be granted unless the Industrial User demonstrates that the constituents of the generic measure in the User's effluent are substantially similar to the constituents of the generic measure in the intake water or unless appropriate additional limits are placed on process water pollutants either at the outfall or elsewhere.

(3) Credit shall be granted only to the extent necessary to meet the applicable categorical Pretreatment Standard(s), up to a maximum value equal to the influent value. Additional monitoring may be necessary to determine eligibility for credits and compliance with Standard(s) adjusted under this section.

(4) Credit shall be granted only if the User demonstrates that the intake water is drawn from the same body of water as that into which the POTW discharges. The Control Authority may waive this requirement if it finds that no environmental degradation will result.

(c) The applicable categorical pretreatment standards contained in 40 CFR subchapter N specifically provide that they shall be applied on a net basis.

(Information collection requirements are approved by the Office of Management and Budget under control number 2040-0009)

Source

[53 FR 40614, Oct. 17, 1988, as amended at 58 FR 18017, Apr. 7, 1993]

§ 403.16 Upset provision.

(a) Definition. For the purposes of this section, Upset means an exceptional incident in which there is unintentional and temporary noncompliance with categorical Pretreatment Standards because of factors beyond the reasonable control of the Industrial User. An Upset does not include noncompliance to the extent caused by operational error, improperly designed treatment facilities, inadequate treatment facilities, lack of preventive maintenance, or careless or improper operation.

(b) Effect of an upset. An Upset shall constitute an affirmative defense to an action brought for noncompliance with categorical Pretreatment Standards if the requirements of paragraph (c) are met.

(c) Conditions necessary for a demonstration of upset. An Industrial User who wishes to establish the affirmative defense of Upset shall demonstrate, through properly signed, contemporaneous operating logs, or other relevant evidence that:

(1) An Upset occurred and the Industrial User can identify the cause(s) of the Upset;

- (2) The facility was at the time being operated in a prudent and workman-like manner and in compliance with applicable operation and maintenance procedures;
- (3) The Industrial User has submitted the following information to the POTW and Control Authority within 24 hours of becoming aware of the Upset (if this information is provided orally, a written submission must be provided within five days):
- (i) A description of the Indirect Discharge and cause of noncompliance;
 - (ii) The period of noncompliance, including exact dates and times or, if not corrected, the anticipated time the noncompliance is expected to continue;
 - (iii) Steps being taken and/or planned to reduce, eliminate and prevent recurrence of the noncompliance.
- (d) Burden of proof. In any enforcement proceeding the Industrial User seeking to establish the occurrence of an Upset shall have the burden of proof.
- (e) Reviewability of agency consideration of claims of upset. In the usual exercise of prosecutorial discretion, Agency enforcement personnel should review any claims that non-compliance was caused by an Upset. No determinations made in the course of the review constitute final Agency action subject to judicial review. Industrial Users will have the opportunity for a judicial determination on any claim of Upset only in an enforcement action brought for noncompliance with categorical Pretreatment Standards.
- (f) User responsibility in case of upset. The Industrial User shall control production or all Discharges to the extent necessary to maintain compliance with categorical Pretreatment Standards upon reduction, loss, or failure of its treatment facility until the facility is restored or an alternative method of treatment is provided. This requirement applies in the situation where, among other things, the primary source of power of the treatment facility is reduced, lost or fails.
- Source

[46 FR 9439, Jan. 28, 1981, as amended at 53 FR 40615, Oct. 17, 1988]



§ 403.17 Bypass.

(a) Definitions. (1) Bypass means the intentional diversion of wastestreams from any portion of an Industrial User's treatment facility.

(2) Severe property damage means substantial physical damage to property, damage to the treatment facilities which causes them to become inoperable, or substantial and permanent loss of natural resources which can reasonably be expected to occur in the absence of a bypass. Severe property damage does not mean economic loss caused by delays in production.

(b) Bypass not violating applicable Pretreatment Standards or Requirements. An Industrial User may allow any bypass to occur which does not cause Pretreatment Standards or Requirements to be violated, but only if it also is for essential maintenance to assure efficient operation. These bypasses are not subject to the provision of paragraphs (c) and (d) of this section.

(c) Notice. (1) If an Industrial User knows in advance of the need for a bypass, it shall submit prior notice to the Control Authority, if possible at least ten days before the date of the bypass.

(2) An Industrial User shall submit oral notice of an unanticipated bypass that exceeds applicable Pretreatment Standards to the Control Authority within 24 hours from the time the Industrial User becomes aware of the bypass. A written submission shall also be provided within 5 days of the time the Industrial User becomes aware of the bypass. The written submission shall contain a description of the bypass and its cause; the duration of the bypass, including exact dates and times, and, if the bypass has not been corrected, the anticipated time it is expected to continue; and steps taken or planned to reduce, eliminate, and prevent reoccurrence of the bypass. The Control Authority may waive the written report on a case-by-case basis if the oral report has been received within 24 hours.

(d) Prohibition of bypass. (1) Bypass is prohibited, and the Control Authority may take enforcement action against an Industrial User for a bypass, unless;

(i) Bypass was unavoidable to prevent loss of life, personal injury, or severe property damage;

(ii) There were no feasible alternatives to the bypass, such as the use of auxiliary treatment facilities, retention of untreated wastes, or maintenance during normal periods of equipment downtime. This condition is not satisfied if adequate back-up equipment should have been installed in the exercise of reasonable engineering judgment to prevent a bypass which occurred during normal periods of equipment downtime or preventative maintenance; and

(iii) The Industrial User submitted notices as required under paragraph (c) of this section.

(2) The Control Authority may approve an anticipated bypass, after considering its adverse effects, if the Control Authority determines that it will meet the three conditions listed in paragraph (d)(1) of this section.

(Information collection requirements are approved by the Office of Management and Budget under control number 2040-0009)

Source

[53 FR 40615, Oct. 17, 1988, as amended at 58 FR 18017, Apr. 7, 1993]

§ 403.18 Modification of POTW pretreatment programs.

(a) General. Either the Approval Authority or a POTW with an approved POTW Pretreatment Program may initiate program modification at any time to reflect changing conditions at the POTW. Program modification is necessary whenever there is a significant change in the operation of a POTW Pretreatment Program that differs from the information in the POTW's submission, as approved under § 403.11.

(b) Substantial modifications defined. Substantial modifications include:

(1) Modifications that relax POTW legal authorities (as described in § 403.8(f)(1)), except for modifications that directly reflect a revision to this Part 403 or to 40 CFR chapter I, subchapter N, and are reported pursuant to paragraph (d) of this section;

(2) Modifications that relax local limits, except for the modifications to local limits for pH and reallocations of the Maximum Allowable Industrial Loading of a pollutant that do not increase the total industrial loadings for the pollutant, which are reported pursuant to paragraph (d) of this section. Maximum Allowable Industrial Loading means the total mass of a pollutant that all Industrial Users of a POTW (or a subgroup of Industrial Users identified by the POTW) may discharge pursuant to limits developed under § 403.5(c);

(3) Changes to the POTW's control mechanism, as described in § 403.8(f)(1)(iii);

(4) A decrease in the frequency of self-monitoring or reporting required of industrial users;

(5) A decrease in the frequency of industrial user inspections or sampling by the POTW;

(6) Changes to the POTW's confidentiality procedures; and

(7) Other modifications designated as substantial modifications by the Approval Authority on the basis that the modification could have a significant impact on the operation of the POTW's Pretreatment Program; could result in an increase in pollutant loadings at the POTW; or could result in less stringent requirements being imposed on Industrial Users of the POTW.

(c) Approval procedures for substantial modifications.

(1) The POTW shall submit to the Approval Authority a statement of the basis for the desired program modification, a modified program description (see § 403.9(b)), or such other documents the Approval Authority determines to be necessary under the circumstances.

(2) The Approval Authority shall approve or disapprove the modification based on the requirements of § 403.8(f) and using the procedures in § 403.11(b) through (f), except as provided in paragraphs (c)(3) and (4) of this section. The modification shall become effective upon approval by the Approval Authority.

(3) The Approval Authority need not publish a notice of decision under § 403.11(e) provided: The notice of request for approval under § 403.11(b)(1) states that the request will be approved if no comments are received by a date specified in the notice; no substantive comments are received; and the request is approved without change.

(4) Notices required by § 403.11 may be performed by the POTW provided that the Approval Authority finds that the POTW notice otherwise satisfies the requirements of § 403.11.

(d) Approval procedures for non-substantial modifications.

(1) The POTW shall notify the Approval Authority of any non-substantial modification at least 45 days prior to implementation by the POTW, in a statement similar to that provided for in paragraph (c)(1) of this section.

(2) Within 45 days after the submission of the POTW's statement, the Approval Authority shall notify the POTW of its decision to approve or disapprove the non-substantial modification.

(3) If the Approval Authority does not notify the POTW within 45 days of its decision to approve or deny the modification, or to treat the modification as substantial under paragraph (b)(7) of this section, the POTW may implement the modification.

(e) Incorporation in permit. All modifications shall be incorporated into the POTW's NPDES permit upon approval. The permit will be modified to incorporate the approved modification in accordance with 40 CFR 122.63(g).

Source

[53 FR 40615, Oct. 17, 1988, as amended at 58 FR 18017, Apr. 7, 1993; 62 FR 38406, 38414, July 17, 1997]

Notes

[EFFECTIVE DATE NOTE: 62 FR 38406, 38414, July 17, 1997, revised this section, effective Aug. 18, 1997.]

§ 403.19 Provisions of specific applicability to the Owatonna Waste Water Treatment Facility.

(a) For the purposes of this section, the term "Participating Industrial Users" includes the following Industrial Users in the City of Owatonna, Minnesota: Crown Cork and Seal Company, Inc.; Cybex International Inc.; Josten's Inc. -- Southtown Facility; SPx Corporation, Service Solutions Division; Truth Hardware Corporation; and Uber Tanning Company.

(b) For a Participating Industrial User discharging to the Owatonna Waste Water Treatment Facility in Owatonna, Minnesota, when a categorical Pretreatment Standard is expressed in terms of pollutant concentration the City of Owatonna may convert the limit to a mass limit by multiplying the five-year, long-term average process flows of the Participating Industrial User (or a shorter period if production has significantly increased or decreased during the five year period) by the concentration-based categorical Pretreatment Standard. Participating Industrial Users must notify the City in the event production rates are expected to vary by more than 20 percent from a baseline production rate determined by Owatonna when it establishes a Participating Industrial User's initial mass limit. To remain eligible to receive equivalent mass limits the Participating Industrial User must maintain at least the same level of treatment as at the time the equivalent mass limit is established. Upon notification of a revised production rate from a Participating Industrial User, the City will reassess the appropriateness of the mass limit. Owatonna shall reestablish the concentration-based limit if a Participating Industrial User does not maintain at least the same level of treatment as when the equivalent mass limit was established.

(c) If a categorical Participating Industrial User of the Owatonna Waste Water Treatment Facility has demonstrated through sampling and other technical factors, including a comparison of three years of effluent data with background data, that pollutants regulated through categorical Pretreatment Standards, other than 40 CFR part 414, are not expected to be present in quantities greater than the background influent concentration to the industrial process, the City of Owatonna may reduce the sampling frequency specified in § 403.8(f)(2)(v) to once during the term of the categorical Participating Industrial User's permit.

(d) If a Participating Industrial User is discharging to the Owatonna Waste Water Treatment Facility in Owatonna, Minnesota and is subject to a categorical Pretreatment Standard other than one codified at 40 CFR part 414, the City of Owatonna may authorize the Participating Industrial User to forego sampling of a pollutant if the Participating Industrial User has demonstrated through sampling and other technical factors, including a comparison of three years of effluent data with background data, that the pollutant is not expected to be present in quantities greater than the background influent concentration to the industrial process, and the Participating Industrial User certifies on each report, with the following statement, that there has been no increase in the pollutant in its wastestream due to activities of the Participating Industrial User. The following statement is to be included as a comment to the periodic reports required by § 403.12(e):

"Based on my inquiry of the person or persons directly responsible for managing compliance with the pretreatment standard for 40 CFR ----, I certify that, to the best of my knowledge and belief, the raw materials, industrial processes, and potential by-products have not contributed this pollutant to the wastewaters since filing of the last periodic report under 40 CFR 403.12(e)."

(e) If the average daily loading from the Participating Industrial Users to the Owatonna Waste Water Treatment Facility is equal to or less than 0.68 pounds per day of chromium, 0.25 pounds per day of copper, 1.17 pounds per day of nickel, and 1.01 pounds per day of zinc, Owatonna may authorize a categorical Participating Industrial User to satisfy the reporting requirements of § 403.12(e) with an annual report provided on a date specified by Owatonna, provided that the Participating Industrial User has no reasonable potential to violate a Pretreatment Standard for any pollutant for which reduced monitoring is being allowed, and has not been in Significant Noncompliance within the previous three years.

(f) The Owatonna Waste Water Treatment Facility in Owatonna, Minnesota shall post public notice of all Significant Noncompliance subject to the publication requirement in § 403.8(f)(2)(vii) at the Minnesota Pollution Control Agency website for a period of one year, as soon as practicable upon identifying the violations. In addition, the Owatonna Waste Water Treatment Facility shall post an explanation of how Significant Noncompliance is determined, and a contact name and phone number for information regarding other, non-Significant Noncompliance violations. If a violation is not corrected within thirty (30) calendar days or results in pass through or interference at the Owatonna Waste Water Treatment Facility, publication must also be made in the format specified in § 403.8(f)(2)(vii).

(g) The provisions of this section shall expire on October 6, 2005.

Source

[65 FR 59738, 59747, Oct. 6, 2000]

Notes

[EFFECTIVE DATE NOTE: 65 FR 59738, 59747, Oct. 6, 2000, added this section, effective Oct. 6, 2000.]

§ 403.20 Pretreatment Program Reinvention Pilot Projects Under Project XL.

The Approval Authority may allow any publicly owned treatment works (POTW) that has a final "Project XL" agreement to implement a Pretreatment Program that includes legal authorities and requirements that are different than the administrative requirements otherwise applicable under this part. The POTW must submit any such alternative requirements as a substantial program modification in accordance with the procedures outlined in § 403.18. The approved modified program must be incorporated as an enforceable part of the POTW's NPDES permit. The Approval Authority must include a re-opener clause in the POTW's NPDES permit that directs the POTW to discontinue implementing the approved alternative requirements and resume implementation of its previously approved pretreatment program if the Approval Authority determines that the primary objectives of the Local Pilot Pretreatment Program are not being met or the "Project XL" agreement expires or is otherwise terminated.

Source

[66 FR 50334, 50339, Oct. 3, 2001]

Notes

[66 FR 50334, 50339, Oct. 3, 2001, added this section, effective Oct. 3, 2001.]

APPENDIX A TO PART 403 -- PROGRAM GUIDANCE MEMORANDUM

U.S. Environmental Protection Agency

Program Guidance Memorandum--61

Subject: Grants for Treatment and Control of Combined Sewer Overflows and Stormwater Discharges.

From: John T. Rhett, Deputy Assistant Administrator for Water Program Operations (WH-546).

To: Regional Administrators, Regions I-X.

This memorandum summarizes the Agency's policy on the use of construction grants for treatment and control of combined sewer overflows and stormwater discharges during wet-weather conditions. The purpose is to assure that projects are funded only when careful planning has demonstrated they are cost-effective.

I. Combined Sewer Overflows

A. Background

The costs and benefits of control of various portions of pollution due to combined sewer overflows and by-passes vary greatly with the characteristics of the sewer and treatment system, the duration, intensity, frequency and areal extent of precipitation, the type and extent of development in the service area, and the characteristics, uses and water quality standards of the receiving waters. Decisions on grants for control of combined sewer overflows, therefore, must be made on a case-by-case basis after detailed planning at the local level.

Where detailed planning has been completed, treatment or control of pollution from wet-weather overflows and bypasses may be given priority for construction grant funds only after provision has been made for secondary treatment of dry-weather flows in the area. The detailed planning requirements and criteria for project approval follow.

B. Planning Requirements

Construction grants may be approved for control of pollution from combined sewer overflows only if planning for the project was thoroughly analyzed for the 20 year planning period:

1. Alternative control techniques which might be utilized to attain various levels of pollution control (related to alternative beneficial uses, if appropriate), including at least initial consideration of all the alternatives described in the section on combined sewer and stormwater control in "Alternative Waste Management Techniques and Best Practicable Waste Treatment" (Section C of Chapter III of the information proposed for comment in March 1974).
2. The costs of achieving the various levels of pollution control by each of the techniques appearing to be the most feasible and cost-effective after the preliminary analysis.
3. The benefits to the receiving waters of a range of levels of pollution control during wet-weather conditions. This analysis will normally be conducted as part of State water quality management planning, 208 area wide management planning, or other State, regional or local planning effort.
4. The costs and benefits of addition of advanced waste treatment processes to dry-weather flows in the area.

C. Criteria for Project Approval

The final alternative selected shall meet the following criteria:

2. Provision has already been made for funding of secondary treatment of dry-weather flows in the area.
3. The pollution control technique proposed for combined sewer overflow is a more cost-effective means of protecting the beneficial use of the receiving waters than other combined sewer pollution control techniques and the addition of treatment higher than secondary treatment for dry-weather municipal flows in the area.
4. The marginal costs are not substantial compared to marginal benefits.

Marginal costs and benefits for each alternative may be displayed graphically to assist with determining a project's acceptability under this criterion. Dollar costs should be compared with quantified pollution reduction and water quality improvements. A descriptive narrative should

also be included analyzing monetary, social and environmental costs compared to benefits, particularly the significance of the beneficial uses to be protected by the project.

II. Stormwater Discharges

Approaches for reducing pollution from separate stormwater discharges are now in the early stages of development and evaluation. We anticipate, however, that in many cases the benefits obtained by construction of treatment works for this purpose will be small compared with the costs, and other techniques of control and prevention will be more cost-effective. The policy of the Agency is, therefore, that construction grants shall not be used for construction of treatment works to control pollution from separate discharges of stormwater except under unusual conditions where the project clearly has been demonstrated to meet the planning requirements and criteria described above for combined sewer overflows.

III. Multi-purpose Projects

Projects with multiple purposes, such as flood control and recreation in addition to pollution control, may be eligible for an amount not to exceed the cost of the most cost-effective single purpose pollution abatement system. Normally the Separable Costs-Remaining Benefits (SCRB) method should be used to allocate costs between pollution control and other purposes, although in unusual cases another method may be appropriate. For such cost allocation, the cost of the least cost pollution abatement alternative may be used as a substitute measure of the benefits for that purpose. The method is described in "Proposed Practices for Economic Analysis of River Basin Projects," GPO, Washington, D.C., 1958, and "Efficiency in Government through Systems Analysis," by Roland N. McKean, John Wiley & Sons, Inc., 1958.

Enlargement of or otherwise adding to combined sewer conveyance systems is one means of reducing or eliminating flooding caused by wet-weather conditions. These additions may be designed so as to produce some benefits in terms of reduced discharge of pollutants to surrounding waterways. The pollution control benefits of such flood control measures, however, are likely to be small compared with the costs, and the measures therefore would normally be ineligible for funding under the construction grants program.

All multi-purpose projects where less than 100% of the costs are eligible for construction grants under this policy shall contain a special grant condition precluding EPA funding of non-pollution control elements. This condition should, as a minimum, contain a provision similar to the following:

Additional special conditions should be included as appropriate to assure that the grantee clearly understands which elements of the project are eligible for construction grants under Pub. L. 92-500.

Source

46 FR 9439, Jan. 28, 1981.

Notes

Sec. 54(c)(2) of the Clean Water Act of 1977, (Pub. L. 95-217) sections 204(b)(1)(C), 208(b)(2)(C)(iii), 301(b)(1)(A)(ii), 301(b)(2)(A)(ii), 301(b)(2)(C), 301(h)(5), 301(i)(2), 304(e), 304(g), 307, 308, 309, 402(b), 405 and 501(a) of the Federal Water Pollution Control Act (Pub. L. 92-500) as amended by the Clean Water Act of 1977 and the Water Quality Act of 1987 (Pub. L. 100-4).

APPENDIX B TO PART 403 [Reserved]

APPENDIX C TO PART 403 [Reserved]

APPENDIX D TO PART 403 -- SELECTED INDUSTRIAL SUBCATEGORIES EXEMPTED FROM REGULATION PURSUANT TO PARAGRAPH 8 OF THE NDRC v. Costle CONSENT DECREE

The following industrial subcategories are considered to have dilute wastestreams for purposes of the combined wastestream formula. They either were or could have been excluded from categorical pretreatment standards pursuant to paragraph 8 of the Natural Resources Defense Council, Inc., et al. v. Costle Consent Decree for one or more of the following four reasons: (1) The pollutants of concern are not detectable in the effluent from the industrial user (paragraph 8(a)(iii)); (2) the pollutants of concern are present only in trace amounts and are neither causing nor likely to cause toxic effects (paragraph 8(a)(iii)); (3) the pollutants of concern are present in amounts too small to be effectively reduced by technologies known to the Administrator (paragraph 8(a)(iii)); or (4) the wastestream contains only pollutants which are compatible with the POTW (paragraph 8(b)(i)). In some instances, different rationales were given for exclusion under paragraph 8. However, EPA has reviewed these subcategories and has determined that exclusion could have occurred due to one of the four reasons listed above.

This list is complete as of October 9, 1986. It will be updated periodically for the convenience of the reader.

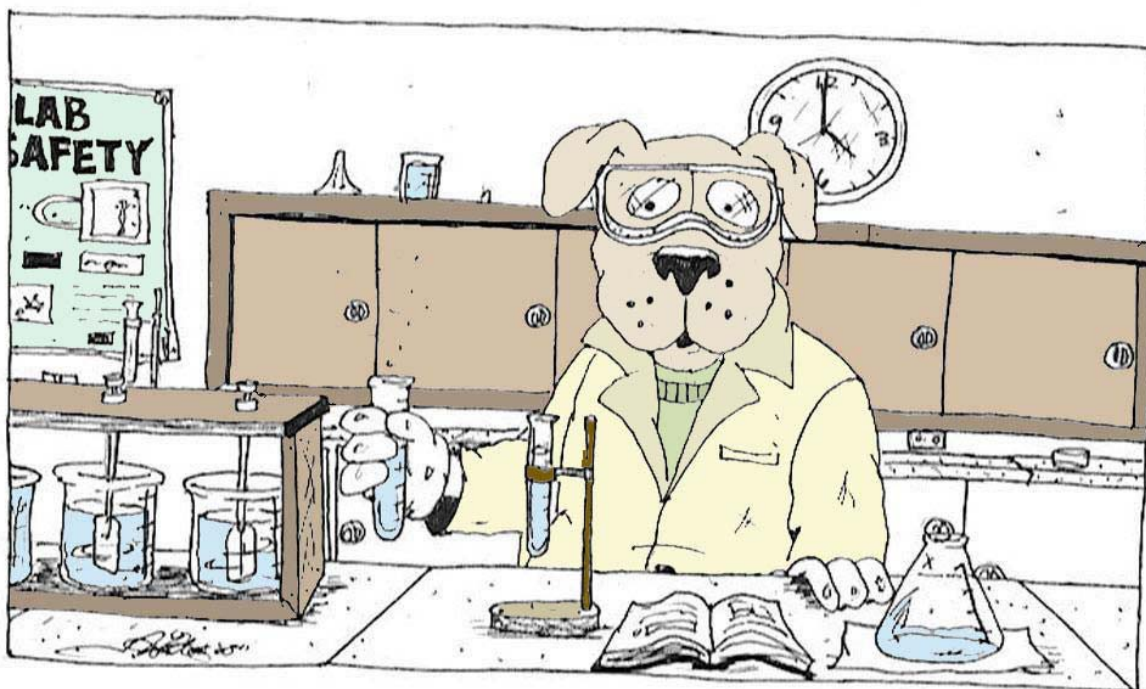
Auto and Other Laundries (40 CFR Part 444)
Carpet and Upholstery Cleaning
Coin-Operated Laundries and Dry Cleaning
Diaper Services
Dry Cleaning Plants except Rug Cleaning
Industrial Laundries
Laundry and Garment Services, Not Elsewhere Classified
Linen Supply
Power Laundries, Family and Commercial
Electrical and Electronic Components ¹ (40 CFR Part 469)
Capacitors (Fluid Fill)
Carbon and Graphite Products
Dry Transformers
Ferrite Electronic Devices
Fixed Capacitors
Fluorescent Lamps
Fuel Cells
Incandescent Lamps
Magnetic Coatings
Mica Paper Dielectric
Motors, Generators, Alternators
Receiving and Transmitting Tubes
Resistance Heaters
Resistors
Switchgear
Transformer (Fluid Fill)
1 The Paragraph 8 exemption for the manufacture of products in the Electrical and Electronic Components Category is for operations not covered by Electroplating/Metal Finishing pretreatment regulations (40 CFR Parts 413/433).
Metal Molding and Casting (40 CFR Part 464)
Nickel Casting
Tin Casting
Titanium Casting
Gum and Wood Chemicals (40 CFR Part 454)

Char and Charcoal Briquettes
 Inorganic Chemicals Manufacturing (40 CFR Part 415)
 Ammonium Chloride
 Ammonium Hydroxide
 Barium Carbonate
 Calcium Carbonate
 Carbon Dioxide
 Carbon Monoxide and Byproduct Hydrogen
 Hydrochloric Acid
 Hydrogen Peroxide (Organic Process)
 Nitric Acid
 Oxygen and Nitrogen
 Potassium Iodide
 Sodium Chloride (Brine Mining Process)
 Sodium Hydrosulfide
 Sodium Hydrosulfite
 Sodium Metal
 Sodium Silicate
 Sodium Thiosulfate
 Sulfur Dioxide
 Sulfuric Acid
 Leather (40 CFR Part 425)
 Gloves
 Luggage
 Paving and Roofing (40 CFR Part 443)
 Asphalt Concrete
 Asphalt Emulsion
 Linoleum
 Printed Asphalt Felt
 Roofing
 Pulp, Paper, and Paperboard, and Builders' Paper and Board Mills (40 CFR Parts 430 and 431)
 Groundwood-Chemi-Mechanical
 Rubber Manufacturing (40 CFR Part 428)
 Tire and Inner Tube Plants
 Emulsion Crumb Rubber
 Solution Crumb Rubber
 Latex Rubber
 Small-sized General Molded, Extruded and Fabricated Rubber Plants, 2
 Medium-sized General Molded, Extruded and Fabricated Rubber Plants 2
 Large-sized General Molded, Extruded and Fabricated Rubber Plants 2
 Wet Digestion Reclaimed Rubber
 Pan, Dry Digestion, and Mechanical Reclaimed Rubber
 Latex Dipped, Latex-Extruded, and Latex-Molded Rubber 3
 Latex Foam 4
 2 Except for production attributed to lead-sheathed hose manufacturing operations.
 3 Except for production attributed to chromic acid form-cleaning operations.
 4 Except for production that generates zinc as a pollutant in discharge.
 Soap and Detergent Manufacturing (40 CFR Part 417)
 Soap Manufacture by Batch Kettle
 Fatty Acid Manufacture by Fat Splitting
 Soap Manufacture by Fatty Acid Neutralization
 Glycerine Concentration

Glycerine Distillation
Manufacture of Soap Flakes and Powders
Manufacture of Bar Soaps
Manufacture of Liquid Soaps
Manufacture of Spray Dried Detergents
Manufacture of Liquid Detergents
Manufacture of Dry Blended Detergents
Manufacture of Drum Dried Detergents
Manufacture of Detergent Bars and Cakes
Textile Mills (40 CFR Part 410)
Apparel manufacturing
Cordage and Twine
Padding and Upholstery Filling
Timber Products Processing (40 CFR Part 429)
Barking Process
Finishing Processes
Hardboard -- Dry Process
Source
[51 FR 36372, Oct. 9, 1986][51 FR 36372, Oct. 9, 1986]

Notes

Sec. 54(c)(2) of the Clean Water Act of 1977, (Pub. L. 95-217) sections 204(b)(1)(C), 208(b)(2)(C)(iii), 301(b)(1)(A)(ii), 301(b)(2)(A)(ii), 301(b)(2)(C), 301(h)(5), 301(i)(2), 304(e), 304(g), 307, 308, 309, 402(b), 405 and 501(a) of the Federal Water Pollution Control Act (Pub. L. 92-500) as amended by the Clean Water Act of 1977 and the Water Quality Act of 1987 (Pub. L. 100-4).



APPENDIX E TO PART 403 -- SAMPLING PROCEDURES

A. It is recommended that influent and effluent operational data be obtained through 24-hour flow proportional composite samples. Sampling may be done manually or automatically, and discretely or continuously. If discrete sampling is employed, at least 12 aliquots should be composited. Discrete sampling may be flow proportioned either by varying the time interval between each aliquot or the volume of each aliquot. All composites should be flow proportional to either the stream flow at the time of collection of the influent aliquot or to the total influent flow since the previous influent aliquot. Volatile pollutant aliquots must be combined in the laboratory immediately before analysis.

B. Effluent sample collection need not be delayed to compensate for hydraulic detention unless the POTW elects to include detention time compensation or unless the Approval Authority requires detention time compensation. The Approval Authority may require that each effluent sample is taken approximately one detention time later than the corresponding influent sample when failure to do so would result in an unrepresentative portrayal of actual POTW operation. The detention period should be based on a 24-hour average daily flow value. The average daily flow should in turn be based on the average of the daily flows during the same month of the previous year.

II. Grab Method

If composite sampling is not an appropriate technique, grab samples should be taken to obtain influent and effluent operational data. A grab sample is an individual sample collected over a period of time not exceeding 15 minutes. The collection of influent grab samples should precede the collection of effluent samples by approximately one detention period except that where the detention period is greater than 24 hours such staggering of the sample collection may not be necessary or appropriate. The detention period should be based on a 24-hour average daily flow value. The average daily flow should in turn be based upon the average of the daily flows during the same month of the previous year. Grab sampling should be employed where the pollutants being evaluated are those, such as cyanide and phenol, which may not be held for an extended period because of biological, chemical or physical interaction which take place after sample collection and affect the results.

Source

[49 FR 31225, Aug. 3, 1984]

Notes

Sec. 54(c)(2) of the Clean Water Act of 1977, (Pub. L. 95-217) sections 204(b)(1)(C), 208(b)(2)(C)(iii), 301(b)(1)(A)(ii), 301(b)(2)(A)(ii), 301(b)(2)(C), 301(h)(5), 301(i)(2), 304(e), 304(g), 307, 308, 309, 402(b), 405 and 501(a) of the Federal Water Pollution Control Act (Pub. L. 92-500) as amended by the Clean Water Act of 1977 and the Water Quality Act of 1987 (Pub. L. 100-4).

APPENDIX G TO PART 403 -- POLLUTANTS ELIGIBLE FOR A REMOVAL CREDIT

I. Regulated Pollutants in Part 503

Eligible for a Removal Credit

Use or disposal practice			
Pollutants	LA	SD	I
Arsenic	X	X	X
Beryllium			X
Cadmium	X		X
Chromium		X	X
Copper	X		
Lead	X		X
Mercury	X		X
Molybdenum	X		
Nickel	X	X	X
Selenium	X		
Zinc	X		
Total hydrocarbons			X fn1

Key:

LA -- land application.

SD -- surface disposal site without a liner and leachate collection system.

I -- firing of sewage sludge in a sewage sludge incinerator.

Notes

fn1 The following organic pollutants are eligible for a removal credit if the requirements for total hydrocarbons in subpart E in 40 CFR Part 503 are met when sewage sludge is fired in a sewage sludge incinerator: Acrylonitrile, Aldrin/Dieldrin(total), Benzene, Benzidine, Benzo(a)pyrene, Bis(2-chloroethyl)ether, Bis(2-ethylhexyl)phthalate, Bromodichloromethane, Bromoethane, Bromoform, Carbon tetrachloride, Chlordane, Chloroform, Chloromethane, DDD,DDE,DDT, Dibromochloromethane, Dibutyl phthalate, 1,2-dichloroethane, 1,1-dichloroethylene, 2,4-dichlorophenol, 1,3-dichloropropene, Diethyl phthalate, 2,4-dinitrophenol, 1,2-diphenylhydrazine, Di-n-butyl phthalate, Endosulfan, Endrin, Ethylbenzene, Heptachlor, Heptachlor epoxide, Hexachlorobutadiene, Alpha-hexachlorocyclohexane, Beta-hexachlorocyclohexane, Hexachlorocyclopentadiene, Hexachloroethane, Hydrogen cyanide, Isophorone, Lindane, Methylene chloride, Nitrobenzene, N-Nitrosodimethylamine, N-Nitrosodi-n-propylamine, Pentachlorophenol, Phenol, Polychlorinated biphenyls, 2,3,7,8-tetrachlorodibenzo-p-dioxin, 1,1,2,2,-tetrachloroethane, Tetrachloroethylene, Toluene, Toxaphene, Trichloroethylene, 1,2,4-Trichlorobenzene, 1,1,1-Trichloroethane, 1,1,2-Trichloroethane, and 2,4,6-Trichlorophenol.

II. ADDITIONAL POLLUTANTS ELIGIBLE FOR A REMOVAL CREDIT

[Milligrams per kilogram -- dry weight basis]

Pollutant	Use or disposal practice			
	Surface disposal			
	LA	Unlined fn1	Lined fn2	I
Arsenic			fn3 100	
Aldrin/Dieldrin (Total)	2.7			
Benzene	fn3 16	140	3400	
Benzo(a)pyrene	15	fn3 100	fn3 100	
Bis(2-ethylhexyl)phthalate		fn3 100	fn3 100	
Cadmium		fn3 100	fn3 100	
Chlordane	86	fn3 100	fn3 100	
Chromium (total)	fn3 100		fn3 100	
Copper		fn3 46	100	1400
DDD, DDE, DDT (Total)	1.2	2000	2000	
2,4 Dichlorophenoxy-acetic acid		7	7	
Fluoride	730			
Heptachlor	7.4			
Hexachlorobenzene	29			
Hexachlorobutadiene	600			
Iron	fn3 78			
Lead		fn3 100	fn3 100	
Lindane	84	fn3 28	fn3 28	
Malathion		0.63	0.63	
Mercury		fn3 100	fn3 100	
Molybdenum		40	40	
Nickel			fn3 100	
N-Nitrosodimethylamine	2.1	0.088	0.088	
Pentachlorophenol	30			
Phenol		82	82	
Polychlorinated biphenyls	4.6	<50	<50	
Selenium		4.8	4.8	4.8
Toxaphene	0	fn3 26	fn3 26	
Trichloroethylene	fn3 10	9500	fn3 10	
Zinc		4500	4500	4500

fn1 Active sewage sludge unit without a liner and leachate collection system.

fn2 Active sewage sludge unit with a liner and leachate collection system.

fn3 Value expressed in grams per kilogram -- dry weight basis.

Key: LA -- land application.

I -- incineration.

Source

[58 FR 9386, Feb. 19, 1993; 60 FR 54764, 54769, Oct. 25, 1995; 64 FR 42552, 42567, Aug. 4, 1999]

Notes

[EFFECTIVE DATE NOTE: 64 FR 42552, 42567, Aug. 4, 1999, revised section II, effective Sept. 3, 1999.]

BEST MANAGEMENT PRACTICES

Background: The definition of Significant Industrial User (SIU) was added to the General Pretreatment Regulation, 40 CFR § 403 on July 24, 1990 and became effective 30 days later. This definition states that;

(1) Except as provided in paragraph (t)(2) of this section, the term Significant Industrial User means:

(i) All industrial users subject to Categorical Pretreatment Standards under 40 CFR 403.6 and 40 CFR Chapter I, Subchapter N; and

(ii) Any other industrial user that: discharges an average of 25,000 gallons per day or more of process wastewater to the POTW (excluding sanitary, noncontact cooling and boiler blowdown wastewater); contributes a process wastestream which makes up 5 percent or more of the average dry weather hydraulic or organic capacity of the POTW treatment plant; or is designated as such by the Control Authority as defined in 40 CFR 403.12(a) on the basis that the industrial user has a reasonable potential for adversely affecting the POTW's operation or for violating any pretreatment standard or requirement (in accordance with 40 CFR 403.8(f)(6)).

(2) Upon a finding that an industrial user meeting the criteria in paragraph (t)(1)(ii) of this section has no reasonable potential for adversely affecting the POTW's operation or for violating any pretreatment standard or requirement, the Control Authority (as defined in 40 CFR 403.12(a)) may at any time, on its own initiative or in response to a petition received from an industrial user or POTW, and in accordance with 40 CFR 403.8(f)(6), determine that such industrial user is not a significant industrial user.

As stated in (1) (ii), above, any other industrial user that has a reasonable potential for violating a pretreatment standard or requirement should be designated as an SIU by the Control Authority, either as per the potential to violate pretreatment standards or by a determination of the potential to cause an adverse effect.

With the implementation of more stringent water quality based effluent limits many municipalities are confronted with the need to include small volume/quantity industrial users in the community of regulated users. This is most apparent when the Publicly Owned Treatment Works (POTW) develops Technically Based Local Limits (TBLLs) and determines the background or unregulated contribution exceeds or approaches the Maximum Allowable Headworks Loading (MAHL).

In these situations the POTW has little choice but to expand the universe of regulated users and begin to address small volume/quantity dischargers, usually grouped by pollutants discharged or by activity. The problem arises when the POTW determines that these small volume/quantity dischargers are a substantial contribution of the target pollutant and controls are necessary to meet NPDES permit limitations or to allow the establishment of equitable TBLLs for the larger volume dischargers.

Typically the small volume/quantity dischargers include; photodevelopers, printing and publishing facilities and medical facilities for silver; radiator and maintenance shops for lead, copper, zinc and cadmium; septic waste haulers for a multitude of pollutants; etc.

Most POTWs are concerned about the reasonableness of issuing permits and expecting these small volume/quantity dischargers to purchase and maintain the pretreatment equipment necessary to comply with TBLLs.

To avoid an adverse situation many POTWs are developing and implementing Best Management Practices (BMPs) for these facilities; the rationale being that the control and reduction of the target pollutant at many facilities will have a significant impact on the total contribution through the sheer number of facilities involved. This scenario is similar to that implemented in Palo Alto, California for silver reduction.

ACTION: The region must therefore establish guidelines, where a POTW determines it is necessary to regulate traditionally non-significant users, to allow for the implementation of BMPs and also demonstrate compliance with the General Pretreatment Regulations. To accomplish this goal the following **minimum** procedures are proposed:

- * All small volume/quantity users within the specified grouping must either be regulated by the BMP guidelines or be permitted.
- * Small volume/quantity users that are permitted are expected to comply with all of the pretreatment regulations pertaining to large volume and categorical SIUs.
- * A list of small volume/quantity users being regulated under the BMP guidelines shall be maintained by the Control Authority and the Control Authority shall issue Letters of Authorization to each facility indicating the facilities intent to comply with the BMP guidelines.
- * The Control Authority must require at least annual reporting by the small volume/quantity users, demonstrating compliance with the BMP guidelines, such as copies of maintenance records for silver recovery equipment or manifests/receipts for septic waste haulers .
- * The BMP guidelines must be incorporated into the Approved Pretreatment Program and established as a pretreatment standard/requirement in an ordinance, thus allowing the intent of the SIU definition to be met (however the BMP regulated users shall not be considered significant industrial users).
- * The POTW must conduct inspections to determine independent of the information supplied by the industrial user compliance with the pretreatment standards. These inspections could be a reduced number from the entire universe, such as a percentage of facilities regulated by the guidelines (the facilities inspected need to change year to year to eventually allow for full coverage).





Definition of Confined Spaces Requiring an Entry Permit

A Confined space is :

1. Is large enough or so configured that an employee can bodily enter and perform work.
2. Has limited or restricted means for entry or exit (i.e. tanks, vessels, silos, storage bins, hoppers, vaults, and pits are spaces that may have limited means of entry).
3. Is not designed for continuous employee occupancy.



PRETREATMENT PROGRAM EVALUATION EXAMPLE

1. Has a change in contributing jurisdictions occurred since the last Annual Report?

Yes No

If yes, identify the jurisdictions that have been added or removed: _____

2. Has the Control Authority updated its Industrial Waste Survey (IWS) to identify new Industrial Users (IUs) or changes in wastewater discharges at existing IUs?
[(403.8(f)(2)(i))]

Yes No

If yes:

- a. Are any of these IUs located in new service areas (describe)? _____

- b. Have any IUs located in contributing jurisdictions where the POTW has no inter-jurisdictional agreements or IU contracts? Yes No

- c. If yes, specify: _____

3. For any new Categorical Industrial Users:

- a. Baseline Monitoring Report (BMR) Submitted? Yes No

- b. Final (90-day) Compliance Report (FCR) Submitted? Yes No

4. How many IUs are currently identified by the Control Authority in each of the following groups?

_____ TOTAL SIUs (as defined by Control Authority)

_____ Categorical Industrial Users (CIUs)

_____ Significant Non-categorical IUs

_____ NDCIUs subject to zero discharge limits

_____ Other regulated non-categorical IUs (Describe):

_____ NDCIUs that are not subject zero discharge categorical limits

5. Is the Control Authority's definition of "**Significant Industrial User**" the same as EPA's? [403.3(t)(1)(i-ii)] Yes No

If not, the Control Authority has defined "**Significant Industrial User**" to mean: _____

6. How many SIUs are required to be covered by an individual control mechanism? _____

How many SIUs are not covered by an existing, unexpired permit or other control mechanism? _____

Explain: _____

7. Were individual control mechanisms issued/reissued for 90% of the SIUs within 180 days of the expiration date? Yes No

How many control mechanisms were not issued within 180 days of the expiration date?

Explain: _____

8. Does the Control Authority have a control mechanism for regulating IUs whose wastes are trucked to the treatment plant? Yes No N/A

If yes, does control mechanism designate a discharge point? Yes No

9. Are all applicable categorical standards and local limits applied to IUs whose wastes are trucked into the POTW? Yes No N/A

If not, why: _____

10. Has the Control Authority evaluated the need for SIUs to develop slug discharge control plans? [403.8(f)(2)(v)] Yes No

If yes, when was the evaluation last conducted and what criteria were used to identify the IUs for slug plans? _____

How many slug control plans were: Required? _____
Received? _____
Approved? _____

11. Are TTO standards or alternatives (solvent management plans or oil & grease monitoring) being implemented for IUs subject to TTO limitations? Yes No N/A

If not, why? _____

Are TTO standards being applied to other IUs? Yes No

12. How many times were the following monitored during the past year?

	Influent	Effluent	Sludge	Ambient (Receiving Water)
Metals				
Priority Poll.				
Biomonitoring				
TCLP				
EP Tox				
Other:				

13. How many, and what percentage of SIUs were (a) not sampled at least twice, or (b) not inspected at least once during the reporting period? [403.8(f)(2)(vi)]

a. Number and % not sampled: _____ (____%)

b. Number and % not inspected: _____ (____%)

14. Does the Control Authority routinely split samples with industrial personnel?

a. If requested: ☐ Yes ☐ No ☐ N/A

b. To verify IU self-monitoring results: ☐ Yes ☐ No ☐ N/A

15. Provide the following analytical information regarding pollutant analyses:

	Analytical Method	Name of Laboratory
Metals		
Cyanide		
Organics		
Other:		

16. Does the Control Authority use QA/QC for sampling and analysis? Yes No

If yes, describe: _____

17. How much time normally elapses between sample collection and obtaining analytical results? _____

18. Is there an established protocol clearly detailing sampling location and procedures?
Yes No

19. Has the Control Authority had any problems performing compliance monitoring?
Scheduled Unscheduled Demand

If yes, explain: _____

20. How frequently does the Control Authority use the closed cup flashpoint test, specified in 40 CFR Part 261.21, to monitor SIUs? [403.5(b)(1)]

_____ Once per year
_____ Prior to each sampling
_____ Other: _____

Did the Control Authority find any problems? Yes No

If yes, explain: _____

21. Does the Control Authority compare all monitoring data to applicable pretreatment standards and requirements contained in the control mechanism within 15 days of its receipt? [403.8(f)(2)(iv)]
Yes No

22. Does the Control Authority use EPA's definition of Significant Noncompliance (SNC)? [403.8(f)(2)(vii)] Yes No

23. Are SIUs required to notify the Control Authority within 24 hours of becoming aware of a violation and to submit additional monitoring within 30 days after the violation is identified [403.12(g)(2)] Yes No N/A

If the Control Authority conducts monitoring in lieu of the user, does the Control Authority resample and obtain results within 30 days of identifying a violation?
Yes No N/A

24. Has the Control Authority developed an Enforcement Response Plan? Yes No

25. For each of the listed enforcement actions, identify the following for the ones the Control Authority has used during the reporting period:

	Total # of Actions	# of Industries Affected
Written notice or letter of violation		
Administrative orders		
Administrative fines		
Show cause hearings		
Compliance orders		
Permit revocation		
Civil action		
Criminal action		
Termination of service		
Other (specify):		

26. Indicate the number and percent of SIUs that were identified as being in SNC (as defined by EPA) with the following during the reporting period:

	# of SNC SIUs	% of SNC SIUs
Applicable pretreatment standards [PSNC]*		
Self-monitoring requirements [MSNC]		
Reporting requirements [PSNC]*		
Pretreatment compliance schedule [SSNC]		
Other:		

27. Did the Control Authority publish all SIUS in SNC in the largest daily newspaper?
[403.8(f)(2)(vii)] Yes No

If yes, attach copy, or attach copy of affidavit of publication.

28. Indicate the number of SIUs that are currently in SNC with self-monitoring and were not inspected or sampled: _____

29. Has the Control Authority experienced any of the following?

	Yes	No	Unknown	Explain:
Interference				
Pass through				
Fire or explosions (including flash point violations)				
Corrosive structural damage (including pH<5.0)				
Flow obstructions				
Excessive flow or pollutant concentrations				
Heat problems				
Interference due to oil or grease				
Toxic fumes				
Illicit dumping of hauled waste				

30. How many SIUs are currently on compliance schedules in order to meet new or revised national pretreatment standards or requirements? _____

Have any CIUs been allowed more than 3 years from the effective date of a categorical standard to achieve compliance? [403.6(b)] es No

31. Indicate the number of SIUs from which penalties have been collected by the Control Authority during the past year:

	Number	Amount (\$)
Civil		
Administrative		
Total		

32. Have IUs requested that data be held confidential? Yes No

33. Have any requests been made by the public to review files? Yes No

34. Has public comment been solicited during revisions to the SUO and/or local limits since the last PCI or audit? [403.5(c)(3)] Yes No N/A

35. Are there significant public or community issues impacting the POTW's pretreatment program? Yes No

If yes, explain: _____

36. Are all records maintained for at least 3 years? Yes No N/A

37. Have any problems in program implementation been observed which appear to be related to inadequate funding, resources or staff? Yes No

If yes, explain: _____

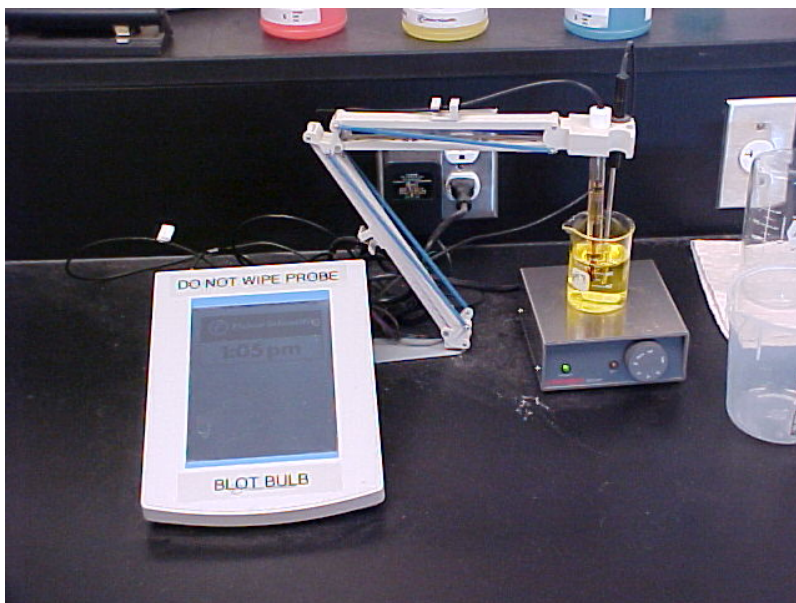
38. Does the Control Authority have the technical documents necessary for implementing its pretreatment program? Yes No

39. Does the Control Authority have access to adequate:

	Yes	No	Explain:
Sampling equipment			
Safety equipment			
Vehicles			
Analytical equipment			



Normal pretreatment equipment found in a regulated industry. pH, ORP and Temperature measuring equipment. Notice the different pH buffers in the upper right of the top photo, and center of the bottom photo. Yellow, red and blue are the normal pH buffers. You are required to calibrate your pH probe at least daily and record your values in a log book. Many States will require a written pH procedure and may require both your log book and procedure in court.



PERMIT COVER SHEET EXAMPLE

Control Authority Name: _____

Treatment Plant Name(s): _____

Permit Number(s): _____

Pretreatment Contact: _____

Title: _____

Address: _____

City, State, Zip Code: _____

Telephone: _____

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

POTW Authorized Signatory

Date

Title

LIST OF REGULATED USERS

[illegible]

INDUSTRIAL SURVEY UPDATE

[illegible]

COMPLIANCE/OVERSIGHT SUMMARY (SIUs ONLY)

[illegible]

B – SNC with Self-Monitoring Requirements
C – SNC with Reporting Requirements
D – SNC with Compliance Schedule

NONCOMPLIANCE/ENFORCEMENT SUMMARY (SIUs ONLY)

[illegible]

Examples of Regulatory and Compliance Letters

December 11, 2015

Mr. D. Robert Kelly
Ajax Well Repair, Inc.
8111 East Montebello Drive
Phoenix, Az. 85777

Dear Mr. Kelly:

RE: DISCHARGE OF WELL MONITORING WATER AT ACME'S PEORIA AVENUE FACILITY

I am in receipt of your letter dated December 4, 2015, in which you requested to discharge approximately 3000 gallons of groundwater generated during the sampling operations of MW-1a thru MW-9 located at, and in the immediate vicinity of, the Acme Peoria Avenue facility, 2250 West Peoria Avenue. The groundwater withdrawn from monitoring wells located at this site is part of a Remedial Investigation / Feasibility Study required by the Arizona Department of Environmental Quality.

Approval is hereby granted for the discharge of approximately 3000 gallons of well purge water. This discharge is anticipated to occur sometime during the period of December 11, through December 16, 2015, to City of Sunflower manholes 124 and 125 in Quarter Section 30-24, and manholes 302 and 403 in Quarter Section 29-23. This discharge shall not exceed a flow rate of 50 gallons per minute, in order to avoid hydraulic overloading of the sewer mains in the area.

This approval is based on a thorough review of the historic analytical data submitted in your letter of September 27, 2015 and 2nd Quarter water quality results submitted with the December 4, 2014 letter. Our review indicates, the Toxic Organics were analyzed using EPA methods 601. All VOC concentrations were found to be less than the Sunflower City Code Instantaneous Effluent Limitations.

It is the opinion of the City of Sunflower Water Quality Division that the wastewater meets all requirements under Chapter 28. The wastewater is also determined not to be in sufficient quantity to injure or interfere with any sewage treatment process, cause corrosive structural damage, constitute a hazard to humans, or create any hazard to the sewer system, or in the receiving waters of the sewage treatment plant.

Please submit your final status report within ten (10) days of the date of discharge. This report shall include the date(s) of discharge, time of day this discharge occurred, and the total gallonage.

Please review the permit thoroughly. Should you have any questions, please contact me at 534-1362. Our office hours are 8:00 a.m. to 5:00 p.m., Monday through Friday.

Sincerely,

MANHOLE ENTRY PERMIT Example

The City of Sunflower, acting through the Water and Wastewater Department, hereby issues a manhole permit to:

Ajax Well Repair, Inc
8111 East Montebello Drive
Suite 116
Tempe, AZ. 85281

hereinafter called Permittee, for the purpose of entering City of Sunflower manhole nos. 124 and 125 in Quarter Section 30-24 and manhole nos. 302 and 403 in Quarter Section 29-23 to dispose groundwater brought to the surface during monitor well pumping test operations at and in the immediate vicinity of:

Acme's Peoria Avenue Facility
7574 West Culver Avenue
Sunflower, Arizona

Prior results from laboratory chemical analyses, from December, 1999 to June, 2015, indicate that concentrations of volatile organic compounds are less than 1000 micrograms per liter. Monitor well water will be sampled and analyzed for volatile organic compounds using EPA methods 601/602 and method 624 for purgeable volatiles. Discharge to the sewer must not exceed 50 gallons per minute, in order to avoid hydraulic overloading of the sewer mains in the area.

The manhole entry permit is issued subject to the following conditions:

1. That the only activities authorized by the permit are for the purposes of removal of the contained wastewater, and that the Permittee conduct no other activity while entering upon the public property authorized by this permit.
2. That the Permittee's activities be conducted only within the time period of December 11, through December 16, 2015, unless authorized in writing by the Water and Wastewater Director for an extension of time, or unless revoked earlier, and that the Permittee notify the Water and Wastewater Department in advance of each separate entry.
3. Permittee shall submit analytical results as established in Section 3 of this permit within 10 days of completing discharge of development and purge waters.
4. Permittee shall incur costs of \$1.0255 per one hundred cubic feet (or current rate as established by water accounting) of ground water discharged.
5. That the Permittee, when finished with the removal and discharge activities, replace to the satisfaction of the Water and Wastewater Director, any manhole covers or other disturbances to the City of Sunflower sewer lines that he caused during the course of his activities.
6. That the Permittee agrees to save and hold harmless, the City, any of its departments, agencies, officers or employees from all costs and damages occurred by any of the above from any damage to any person or property whatsoever which is caused by the activity, condition or event arising out of the negligent performance or nonperformance of any of the provisions of this permit by the Permittee any of the Permittee's agents, or any of the

Permittee's independent contractors. The above costs incurred by the City, any of its departments, agencies, officers or employees shall include in the event of any action, court cost, expensive litigation and reasonable attorney fees. When any of the above costs and/or damages occur as aforesaid, the Permittee assumes the burden of proof that the negligent activity, condition or event did not cause such cost damage or other expense the City may incur.

The Permittee agrees to the condition set forth in this permit, and understands that all activities done under the conditions of this permit should conform to the laws of the City of Sunflower and the State of Arizona.

Dated this _____ day of _____, 2015.

Permittee

Dated this _____ day of _____, 2015.

CITY OF SUNFLOWER,
a municipal corporation

By: _____
Chris Binder
Chief Water Quality Inspector
Water Services Department

<u>MANHOLE NO.</u>	<u>QUARTER SECTION</u>	<u>DESCRIPTION OF LOCATION</u>
MH 124	30-24	5 feet west of center line in 21st Avenue approximately 150 feet north of center line of Fred Street. For monitor well MW-6.
MH 125	30-24	1 foot of center line in 23rd Avenue and approximately 140 feet south of center line in Frank Street. For monitor well MW-5.

September 1, 2016

Mr. Dewey Hopkins, President
Acme Technical Casting, Inc.
8111 East Montebello Street
Sunflower, Arizona 85040

Certified Mail
Return Receipt Requested

**Re: Confirmation of Wastewater Discharge Permit Reclassification From
Class A to Class B**

Dear Mr. Myers:

I am writing this letter to acknowledge your meeting on August 29, 2016 with Chris Binder, Chief Water Quality Inspector, and to confirm the City of Sunflower' (City) decision to reclassify the permit status of Acme Technical Casting, Inc. (Acme) from "**Class A**" to "**Class B**." While the reasons forming the basis for this decision were briefly discussed at the meeting, I believe it necessary to recite them here so that Acme thoroughly understands why the City made this decision.

BACKGROUND INFORMATION

The information contained in this portion of my letter is based upon documentation contained in our file, observations made by City Water Quality Inspectors during on-site inspections and various meetings with Acme representatives.

Acme manufactures investment castings for commercial and aerospace applications using ferrous and non-ferrous metals. Pretreatment consists of a closed loop recirculating filtration system. There is no categorical discharge to the sanitary sewer. Any sludge resulting from the manufacturing process is disposed of accordingly.

There are no floor drains in the production area. The floor is bermed and sloped to a sump in the pretreatment area. All categorical process discharge lines have been cut and plugged. This has been verified by on-site inspections performed by City Water Quality Inspectors. The wastewater discharge of approximately 4000 gallons per day (gpd) consists of non-federally regulated penetrant and X-ray rinses, in addition to sanitary wastes.

Even though the manufacturing operation is regulated by the 40 CFR 464.15(f) and 40 CFR 464.36(e)(2), metal molding and casting category, there is no discharge of this process wastewater to the sanitary sewer. Therefore, Acme does not conduct any activities that are regulated by the federal categorical standards contained in 40 CFR Chapter I, Subchapter N (parts 405-471). However, Acme is required to comply with 40 CFR 403 and Chapter 28 of the Sunflower City Code. Acme has been permitted as a Significant Industrial User (SIU) since June 24, 1991.

Acme has had two effluent violations in the past four years. Both were for exceeding the silver limitation, and the last violation occurred on September 5,

2016. Acme received the Mayor's Award recognizing full compliance with pretreatment requirements for the year 2006.

The total daily poundage from the biological oxygen demand (BOD) and suspended solids (SS) concentrations of the process wastewater is approximately 9.5 pounds. This is substantially less than the equivalent strength of 25,000 gpd of domestic waste when measured by BOD and SS (approximately 75 pounds).

PERMITTING STRUCTURE

As you know, the wastewater discharge permitting requirements are contained in Chapter 28 of the Sunflower City Code. When Acme was first issued a permit, the City only issued permits to SIU's. Due to its federal categorical discharge flows, Acme was designated in 1997 as a SIU. The City has since revised its permitting structure to allow for the issuance of non-SIU permits to other industrial users. The SIU permits are designated as Class A, with the non-SIU permits falling into the Class B category.

DECLASSIFICATION ANALYSIS

When a SIU permit is up for renewal, or when the City is made aware of changes made by the SIU that could change the status of the existing Class A permit, the City reviews all relevant information to determine (1) whether the SIU should continue to be classified as a SIU and therefore be issued a Class A permit; or (2) whether the industrial user qualifies for a Class B Permit. A Class B permit generally contains less restrictive requirements than a Class A permit.

Section 10-45.1 of the City Code allows industrial users to be issued a Class B permit if they: (1) are a zero process discharge user; (2) discharge the equivalent strength of 25,000 gallons per day of domestic waste as measured by BOD (Biological Oxygen Demand) and SS (Suspended Solids); (3) discharge polluted groundwater; or (4) discharge any of the substances identified in Sections 28-9 and 28-45(b) of the City Code.

Eligibility for a B permit is for those users discharging less than 25,000 gpd of process wastewater and there are no discharges of any federal categorical process wastewater. It is evident from the Background Section of this letter that Acme met this threshold requirement.

Our next step was to gather and evaluate additional information to determine whether Acme discharges causes or has the reasonable potential to cause harm or damage to the City's wastewater treatment plants, worker safety, public safety or to the environment. Without going into detail over everything that was considered, we did ask ourselves the following questions:

1. What is the average annual water consumption at the facility?

2. What are the process wastewater biological demand and suspended solids concentrations?
3. What types of activities are conducted on the site?
4. Is there a reasonable potential for adversely affecting the City's wastewater treatment plant operation or for violating any pretreatment standard or requirement?
5. Does the discharge pose a health and safety concern to Water Services personnel?
6. What is the compliance history of the facility?
7. What is the existence and effectiveness of pretreatment used by the facility?
8. Has there been any receipt of any environmental awards (e.g., Mayor's Recognition of Achievement for Full Compliance With Pretreatment Requirements)?
9. Does the facility have a written policy or philosophy pertaining to environmental matters and is it being followed?
10. Has the facility always exhibited good faith efforts in complying with Chapter 28 requirements?
11. Is this a special discharge under Section 28-45.1 of the Sunflower City Code?

Based upon all of the foregoing considerations, the City has reclassified the permit status of Acme from a Class A permit to a Class B permit.

WHAT RECLASSIFICATION MEANS TO YOU

- 1) Effective July 1, 2016, Wastewater Discharge Permit No. 9405-2910 is rescinded. Acme is no longer designated as a Significant Industrial User under Section 28-45 of the Sunflower City Code.
- 2) On or before September 15, 2016, Acme will be issued a Class B Wastewater Discharge Permit.
- 3) Effective July 1, 2016, Acme will not be subject to the annual permitting fee contained in Section 28-39(h) of the City Code. This information will be provided to the City's Customer Service Division of the Water Services Department and any adjustments will be made on a future billing statement.

- 4) Acme will no longer be eligible for the Mayor's Recognition of Achievement Award for Full Compliance with Pretreatment Requirements since the award is only given to Class A permittees. However, the City is considering whether to have some type of award for Class B Permit holders.
- 5) Please be aware that even though Acme is not a SIU based upon the facts as they exist today, this designation can change if the basis for our decision to issue a Class B Permit is no longer valid. For example, changes in your zero discharge of categorical process wastewater status so that Acme now has categorical process wastewater flow to the sanitary sewer will require a reclassification and return to SIU status. The City will review your permit classification status on an annual basis, or more frequently if warranted under the circumstances.

CONCLUSION

Acme will receive a Class B wastewater discharge permit under our new permitting structure. We are confident that Acme will continue to be responsible and use sound and prudent judgment in the handling of its wastewater discharges.

Chris Binder, Senior Water Quality Inspector, is the inspector that has been assigned to your facility. Please feel free to contact him at 474-8888 should you have any questions pertaining to your new permit.

Sincerely,

Bill Fields
Water Quality Supervisor

HIGH STRENGTH DISCHARGE PERMIT EXAMPLE

Facility Name: ACME Services Group of Sunflower

Facility Address: 8111 West Montebello Street
Sunflower, Arizona 85297

Mail Address: 8111 West Montebello Street
Sunflower, Arizona 85297

PERMIT EFFECTIVE DATE: January 1, 2015

PERMIT EXPIRATION DATE: December 31, 2016

In accordance with the Permit Application filed by **ACME Services Group (ACME)** on **01/02/02** with the City of Sunflower Pollution Control Division, this High Strength Discharge Permit (Permit) is granted to the above facility (i.e., Permittee) to discharge process wastewater to the City of Sunflower (City) Sanitary Sewer Collection System in accordance with the terms and conditions of this Permit.

The Permittee shall comply with Chapter 10 of the Sunflower City Code, all federal and state laws and regulations pertaining to the Permittee's discharge and all provisions of this Permit.

This Permit replaces all previously issued Permits. If you believe that the City should reconsider the conditions and limitations of this Permit you have the right to file a Petition for Review within twenty (20) days of your receipt of this Permit. A copy of Section 10-46.1 governing the Permit Appeals Process is attached.

Date of Issue: December 30, 2015
Modified on **January 13, 2016**

Chris Binder
Water Quality Supervisor

I. SPECIFIC REQUIREMENTS

A. Discharge Limitations

1. The Permittee is authorized to discharge previously collected human wastes from portable toilets through a private manhole on their property, and truck/toilet washing/maintenance operation discharges to the compliance sampling point described as a **three inch Parshall flume vault located at the northwest corner of the property approximately 20 feet west of the driveway.**
2. The compliance sampling point is illustrated in Attachment A of this Permit.

2. Flow volume through the compliance sampling point averages 4,500 gallons per day but in no event shall exceed 7,000 gallons during any single day.
3. During the term of this Permit, all discharges shall comply with the general user requirements contained in Section 10-8 of the Sunflower City Code.

B. Sampling Requirements and Procedures

1. Permittee shall sample once per month (starting the month of January 2001) for arsenic, copper, lead, and mercury by the taking of a composite sample, and pH, total petroleum hydrocarbons (TPH) and total sulfides, by the taking of grab samples at the compliance sampling point. The pH shall be within the instantaneous limits of 5.0 - 10.5 s.u. (standard units). The TPH shall be 100 mg/l or less. There is no numerical limit at this time associated with the metals, or sulfide samples.
2. All samples shall be taken at the compliance sampling point specified in this Permit and, unless otherwise specified, before the wastewater joins or is diluted by any other wastestream, body of water or substance. All equipment used for sampling and analysis must be routinely calibrated and inspected and maintained to ensure accuracy. The sampling point shall not be changed without written approval of the City.
3. Sampling and analysis of these samples shall be performed in accordance with the techniques prescribed in 40 CFR Part 136, as may be amended. For TPH analysis, use EPA method 418.1.
4. If required, appropriate flow measurement devices shall be selected and used to ensure the accuracy and reliability of measurements of the volume of monitored discharges. Devices shall not be installed without prior written approval from the City.

C. Periodic Monitoring Report Required

1. All reporting (including written notifications, oral notifications and discharge sampling reports) required by this Permit shall, unless otherwise specified, be addressed to:
City of Sunflower
Water Services Department
Pollution Control Division
1534 West Montebello
Sunflower, Arizona 85297
2. Each submitted discharge sampling report, written notification, or any other report required by this Permit, must be signed (see Part II. N of this Permit for signatory requirements).

3. Sampling results shall be summarized and reported on a High Strength Discharge Monitoring Report Form provided by the City. This report is due on the last day of each month and is to include all results of monitoring performed during that calendar month as well as information required for the prior calendar month that has not been previously submitted. The report must be received at the above address no later than the due date so as not to be considered late. The first report is due no later than January 31, 2001. Each report should indicate the results of all sampling as set forth in Part I (B) and (G) of this Permit. Reports must also be submitted during months in which no wastewater discharge occurred and include a zero discharge certification statement on a form provided by the City.
4. If Permittee samples more frequently at the compliance sampling point than required by this Permit, using test procedures approved under 40 CFR Part 136 or as specified in this Permit, the results of such sampling shall be reported in the monthly report.

D. pH Log Book

Permittee is required to maintain a log book of pH measurements showing date and time of measurement, name of the person performing the measurement, and pH meter calibration data for all samples collected at the compliance sampling location.

E. Maintenance of Compliance Monitoring Point

1. Permittee shall maintain the compliance sampling point, illustrated in Attachment A, in continuously efficient operations at all times.
2. Permittee is required to keep written documentation of maintenance which includes at least the following:
 - a. Date of service;
 - b. Who performed the service (contractor name or Permittee employee name and title);
 - c. Nature of service (repaired - nature of repair, inspection, cleaned, etc.).

F. Maintenance of Pretreatment Interceptors

1. Permittee is required to maintain the two stage seven hundred fifty gallon sand/oil interceptor located approximately 6 feet west of the toilet cleaning pad and the three stage, two thousand gallon interceptor located 25 feet west of the northwest corner of the maintenance shop building which receives wastewater from the truck/toilet washing/maintenance operation in continuously efficient operations at all times.

2. Permittee is required to maintain written documentation of both of the interceptor's maintenance which includes at least the following:
 - a. Date of service;
 - b. Who performed the service (contractor name or Permittee name and title).
 - c. Nature of service (pumped, repaired -- nature of repair, inspection, etc.)

G. Access Restrictions/Security /Special Sampling Requirements

1. Beginning February 1, 2001, permittee will perform screening tests on samples collected from individual trucks prior to discharge to the compliance sampling point, on a random basis picked by a computer system, for the following parameters and according to the following schedule:

- a. The following will be tested on every truck:

<u>PARAMETER</u>	<u>ACCEPTABLE CRITERIA</u>
PH	5.0 - 10.5 s.u.
ORP	-500 to +500 mv
Temperature	150° F or less

- b. From February 1, 2015 through July 31, 2001, a minimum of one truck per day will be tested for the following:

<u>PARAMETER</u>	<u>ACCEPTABLE CRITERIA</u>
Colorimetric analysis:	
Cyanide (filtered sample)	2.0 mg/L
Chromate (filtered sample)	0.5 mg/L
Copper (filtered sample)	10.0 mg/L

Test Paper:

Lead	5.0 mg/L
Organic Solvent/Petroleum Hydrocarbons	10 mg/L gasoline
Oxidizer	3.0 mg/L as H ₂ O ₂
Fluoride	20 mg/L
Iodine, Bromine, Chlorine	1 mg/L

- c. After the expiration of the time period in part b above, for the remaining term of this permit, a minimum of three trucks per week will be tested for those parameters identified in part b.
- d. In addition, a minimum of one sample every month will be collected from a truck and analyzed by a licensed laboratory for arsenic, copper, lead and mercury.

- e. If any of the parameters identified above exceed the Acceptable Criteria, then the load will be temporarily stored in the 1,000 gallon above ground holding tank and handled as set forth in subparagraph 6 of this paragraph G.
- f. The City anticipates that the sampling frequencies and Acceptable Criteria contained in this paragraph G may need to be changed based upon the sampling generated from February 1, 2001 through July 31, 2015, and in such event this Permit will be amended accordingly. However, until this Permit is amended, the sampling frequencies and Acceptable Criteria contained in this paragraph G will remain in effect.

Permittee will include all results of individual truck testing with monthly reports as required in Part I. C . of this Permit.

- 2. Prior to February 1, 2015, Permittee will purchase, install and maintain a locked manhole cover over the truck discharge point, with access being limited to a select number of Permittee's employees having keys.
- 3. Prior to March 1, 2015, Permittee will issue a form letter to all existing customers (and thereafter on an annual basis) and to each new customer at time of initial service, placing that customer on notice that any discharge of foreign material into portable toilets is prohibited.
- 4. Prior to March 1, 2015, Permittee will conspicuously label all portable toilets with a warning that any disposal of foreign substance into portable toilets is unlawful and may lead to fines and/or prosecution.
- 5. Permittee will provide all current service drivers and employees (prior to March 1, 2015) and future portable service drivers (within 15 days of hiring) with training to detect the presence of foreign material in the portable toilets. In addition to acknowledging the training provided by Permittee, all drivers will sign a separate Acknowledgement of Training Form stating their understanding of the following procedures:
 - a. All drivers will perform visual and olfactory inspections of each toilet for foreign material prior to and while pumping portable toilets;
 - b. In the event foreign material is detected during these inspections, the driver will notify Permittee's Facility Operations via mobile radio or telephone immediately;
 - c. The driver will tag the unit with a Bypass Ticket notifying the customer of the nature of the problem. The driver shall also

attempt to contact a responsible party on the job site and advise that party to contact Permittee's office;

- d. The driver will turn in the route card or route sheet with a copy of the Bypass Ticket to operations at the end of the route;
- e. ACME Operations will then remove that unit from the route and forward the Bypass Ticket to the sales department for customer contact and resolution;
- f. The ACME Sales Department will notify the customer of their responsibility to legally dispose of the foreign material. The customer will be advised to contact the ACME Sales Department when the foreign material has been removed;
- g. Upon notification of removal by the customer, the sales department will notify ACME Operations. ACME Operations will conduct a field inspection of the unit and reinsert the unit into the route for service;
- h. Any unit containing foreign material will not be removed from a particular job site until the customer has appropriately addressed the removal of the foreign material.

All signed Acknowledgement Training Forms will be placed in each employee's personnel file and be made available to City personnel during inspections. This employee training will be incorporated into Permittee's general monthly employee meetings, a record of which shall be maintained at the facility.

6. Prior to March 1, 2015, the Permittee will install and maintain a one thousand (1000) gallon above ground tank at the facility. If a questionable wastestream is determined while testing, that particular waste load will be temporarily stored in this tank. The contents will be retested by a licensed laboratory for a complete list of parameters as determined by the City. Should the retest confirm the wastestream is not suitable for discharge to the compliance point, the contents will be disposed of in a manner as required by state and federal law. At no time will Permittee discharge a questionable load to the sanitary sewer.

II. HIGH STRENGTH DISCHARGE PERMIT STANDARD CONDITIONS

A. Permittee Shall Provide Notice of Changes

Any changes, permanent or temporary, to the premises or operations that significantly change the quality or volume of the wastewater discharge or other changes that have occurred which differ from what was stated in the Permit application shall be reported by the Permittee 90 days prior to making the changes.

B. Permittee Shall Provide Notification of Noncompliance

Permittee shall notify the City within 24 hours of becoming aware of a discharge which is known or suspected to be in violation with any limitation or provision of this Permit, including an accidental spill of substances prohibited by Section 10 of the Sunflower City Code.

C. Permittee Shall Provide Information

The Permittee shall furnish to the Pollution Control Division, by the date requested, any information to determine whether cause exists for modifying or revoking this Permit, or to determine compliance with this Permit. The Permittee shall also furnish to the Pollution Control Division, upon request, copies of records required by this Permit to be kept by the Permittee.

D. Inspection and Entry of Facility

The Permittee shall provide free access to all areas of the facility to an authorized representative of the Pollution Control Division, upon the presentation of credentials and other documents as may be required by law, to:

1. Enter at any time during normal hours of operation upon the Permittee's premises where a regulated facility or activity is located or conducted, or where records must be kept under the conditions of this Permit;
2. Have access to and copy, at reasonable times, any records that must be kept under the conditions of this Permit;
3. Inspect at reasonable times any facilities, equipment (including monitoring and control equipment), practices, or operations regulated or required under this Permit and any production, or storage area where discharge regulated under this Permit, could originate or may be subject to regulation; and
4. Sample or monitor, for the purposes of assuring Permit compliance, any substances or parameters at any location.

E. Permittee Shall Retain Records

1. The Permittee shall retain on site, copies of all reports required by this Permit, including all emergency response procedures and incident documentation and records of all data used to complete the application for this Permit, for a period of at least three years from the date of the document preparation.
2. All records which pertain to matters that are the subject of special orders or any other enforcement or litigation activities brought by the Pollution Control Division shall be retained and preserved by the Permittee until all enforcement activities have concluded and all periods of limitation with respect to any and all appeals have expired.
3. The Permittee shall retain records of all monitoring information, including all calibration and maintenance records and all original strip chart recordings for continuous monitoring instrumentation, for a period of at least three years from the date of the sample or measurement.
4. Sampling records shall contain the following:
 - a. The date, exact place, time, and methods of sampling or measurements, and sample preservation techniques or procedures;
 - b. Who performed the sampling or measurements;
 - c. The date(s) analyses were performed;
 - d. Who performed the analyses;
 - e. The analytical techniques or methods used; and
 - f. The results of such analyses.

5. Additional Sampling by the Permittee

If the Permittee samples more frequently than required by this Permit, using approved test procedures or as specified in this Permit, the results of this monitoring shall be maintained as a part of Permittee's records for a period of at least three years from the date of the sampling.

F. Emergency Response Procedures and Incident Documentation Reports

1. Permittee shall have emergency response procedures which, at a minimum, identify how to document the incident(s) or other event(s) that does or may result in a discharge in excess of the Permit limitations to the sanitary sewer and identifies the agency(s) and

official(s) to notify in case of a spill or need to discharge this process wastewater to the sanitary sewer.

2. Emergency incident documentation requirements shall at a minimum include:
 - a. date, time of emergency
 - b. description of emergency including discharge constituents and quantity
 - c. documentation of agency and agency official notification
 - d. cause of emergency
 - e. corrective actions taken or to be taken to correct the incident
 - f. corrective action plan to prevent a future incident
 - g. report on compliance with corrective action schedule(s)
3. Any emergency incident causing a wastewater discharge to the sanitary sewer does not relieve the Permittee from the requirements set forth in 40 CFR Part 403, Chapter 10 of the City Code and this Permit.

G. Duty to Reapply; Automatic Extension of Permit

If Permittee wishes to continue an activity regulated by this Permit after the expiration date of this Permit, Permittee must apply for and obtain a new Permit. The application must be submitted at least 60 calendar days before the expiration date of this Permit. Subject to the City's right to amend, or, revoke this Permit, or to deny a new Permit, this Permit shall automatically continue to remain in full force and effect after the expiration date if Permittee has timely filed the Permit application and a new Permit is not issued prior to the Permit expiration date.

H. Permit Modification

This Permit may be modified by the City:

1. To incorporate any new or revised federal, state, or local pretreatment standards or requirements;
2. To make changes due to material or substantial alterations or additions to the Permittee's operation which were not covered in the issued Permit;
3. To correct any errors;
4. To make changes that are deemed reasonably necessary to prevent pass through or interference, protect the quality of the water body receiving the treatment plant's effluent, protect worker health and safety, facilitate sludge management and disposal, protect against damage to the POTW and to ensure user compliance with Chapter 10 of the Sunflower City Code or state and federal laws, rules and regulation.

I. Permit Revocation

This Permit may be revoked for good cause, including but not limited to:

1. failure to notify the City of significant changes to the wastewater prior to the changed discharge;
2. failure to provide prior notification to the City of changed conditions pursuant to Section 10-44(f) of the Sunflower City Code;
3. misrepresentation or failure to fully disclose all relevant facts in the wastewater discharge Permit application;
4. falsifying self-monitoring reports;
5. tampering with monitoring equipment;
6. refusing to allow the City timely access to the facility premises and records;
7. failure to meet effluent limitations;
8. failure to pay fines and penalties;
9. failure to pay sewer charges;
10. failure to meet compliance schedules;
11. failure to complete a wastewater survey or the Permit application;
12. failure to provide advance notice of the transfer of business ownership of a Permitted facility; or
13. violation of any pretreatment standard or requirement, or any terms of the Permit or requirement of Chapter 10 of the Sunflower City Code; or
14. when the City has determined that a Permit reclassification is required.

J. Permit Not a Property Right

The issuance of this Permit does not convey any property rights of any sort, or any exclusive privileges, nor does it authorize any injury to private property or any invasion of personal rights, nor any infringement of federal, state or local laws or regulations.

K. Non-Transferability of Permit

This Permit is not transferable to any person. In the event of sale or change of ownership the Permittee shall provide written notice to the Pollution Control Division thirty (30) days prior to the effective date of sale or change of ownership.

L. Severability

The provisions of this Permit are severable. If any provision of this Permit, or the application of any provision of this Permit to any circumstances is held invalid, the application of such provision to other circumstances, and the remainder of this Permit, shall not be affected thereby.

M. Civil and Criminal Penalties

Any violation of this Permit can result in both civil and criminal penalties that are in addition to all remedies available to the City set forth in Chapter 10 of the Sunflower City Code. Civil Penalties can be \$25,000 per day per violation. Criminal misdemeanors can result in fines of \$2500.00 per day per violation in addition to imprisonment of 6 months.

N. Signatory Requirements

Permit applications, correspondence and all reports shall be signed by the appropriate signatory:

1. For a corporation: by a corporate officer or other persons performing a similar policy or decision-making function for the corporation;
2. For a partnership or sole proprietorship: by a general partner or the proprietor, respectively;
3. All applications, correspondence, reports, and self-monitoring reports may be signed by a duly authorized representative of the person described above. A person is a duly authorized representative only if:
 - a. the authorization is made in writing by a person described above; and
 - b. the authorization specified either an individual or a position having responsibility for the overall operation of the regulated facility or activity, such as the position of plant manager, superintendent, or position of equivalent responsibility. (A duly authorized representative may thus be either a named individual or any individual occupying a named position).
4. Any person signing a document required under this Permit shall make the following certification:

"I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations."

GAS METER CALIBRATION LOG

Meter # _____

[illegible]

Confined Space Entry Program

Purpose

The Confined Space Entry Program is provided to protect authorized employees that will enter confined spaces and may be exposed to hazardous atmospheres, engulfment in materials, conditions which may trap or asphyxiate due to converging or sloping walls, or contains any other safety or health hazards.

Reference: OSHA-Permit-Required Confined Spaces (**29 CFR 1910.146**).

Scope

You are required to recognize the dangers and hazards associated with confined spaces, and this program is designed to assist you in the safety of and compliance with the OSHA standards associated with such.

Most WWTP's will utilize the Fire Department for all rescues and additional assistance dealing with confined spaces, understanding that most Fire Department operations utilize additional in house SOG's/SOP's pertaining to such operations.

Definitions

Confined space:

- Is large enough or so configured that an employee can bodily enter and perform work.
- Has limited or restricted means for entry or exit (i.e. tanks, vessels, silos, storage bins, hoppers, vaults, and pits are spaces that may have limited means of entry).
- Is not designed for continuous employee occupancy.

Permit required confined space (permit space), is a confined space that has one or more of the following characteristics:

1. Contains or has a potential to contain a hazardous atmosphere.
2. Contains a material that has the potential for engulfing an entrant.
3. Has an internal configuration such that an entrant could be trapped or asphyxiated by inwardly covering walls or by a floor which slopes downward and tapers to a smaller cross-section.
4. Contains any other recognized serious safety or health hazard.



Each Permit-Required Confined Space will be marked "Confined Space - Entry Permit Required".



Examples of ***“Permit Required Confined Spaces.”*** Make sure you comply with these Confined Space rules or face civil and/or criminal charges. Several states have criminally charged Supervisors and Attendants for the actions of the employees in a Confined Space/Permit Required Confined Space. ***Don’t risk death or the chance of going to jail in order to speed up your job!***



Confined Space Hazards

Fatalities and injuries constantly occur among construction workers who, during the course of their jobs, are required to enter confined spaces. In some circumstances, these workers are exposed to multiple hazards, any of which may cause bodily injury, illness, or death.

Newspaper and magazine articles abound with stories of workers injured and killed from a variety of atmospheric factors and physical agents. Throughout the construction jobsite, contractors and workers encounter both inherent and induced hazards within confined workspaces.

Inherent Hazards

Inherent hazards, such as electrical, thermal, chemical, mechanical, etc., are associated with specific types of equipment and the interactions among them.

Examples include high voltage (shock or corona discharge and the resulting burns), radiation generated by equipment, defective design, omission of protective features (no provision for grounding non-current-carrying conductive parts), high or low temperatures, high noise levels, and high-pressure vessels and lines (rupturing with resultant release of fragments, fluids, gases, etc.).

Inherent hazards usually cannot be eliminated without degrading the system or equipment, or without making them inoperative. Therefore, emphasis must be placed on hazard control methods.

Induced Hazards

Induced hazards arise, and are induced from, a multitude of incorrect decisions and actions that occur during the actual construction process. Some examples are: omission of protective features, physical arrangements that may cause unintentional worker contact with electrical energy sources, oxygen-deficient atmospheres created at the bottom of pits or shafts, lack of safety factors in structural strength, and flammable atmospheres.

Typical Examples of Confined Workspaces

Following are typical examples of confined workspaces in construction which contain both inherent and induced hazards.

Vaults

A variety of vaults are found on the construction jobsite. On various occasions, workers must enter these vaults to perform a number of functions.

The restricted nature of vaults and their frequently below-grade location can create an assortment of safety and health problems.

Oxygen-Deficient Atmosphere

One of the major problems confronting construction workers while working in vaults is the ever-present possibility of an oxygen-deficient atmosphere.

Explosive or Toxic Gases, Vapors, or Fumes

While working in an electrical vault, workers may be exposed to the build-up of explosive gases such as those used for heating (propane). Welding and soldering produce toxic fumes which are confined in the limited atmosphere.

Electrical Shock

Electrical shock is often encountered from power tools, line cords, etc. In many instances, such electrical shock results from the fact that the contractor has not provided an approved grounding system or the protection afforded by ground-fault circuit interrupters or low-voltage systems.



Purging

In some instances, purging agents such as nitrogen and argon may enter the vault from areas adjacent to it. These agents may displace the oxygen in the vault to the extent that it will asphyxiate workers almost immediately.

Materials Falling In and On

A hazard normally considered a problem associated with confined spaces is material or equipment which may fall into the vault or onto workers as they enter and leave the vault.

Vibration could cause the materials on top of the vault to roll off and strike workers. If the manhole covers were removed, or if they were not installed in the first place, materials could fall into the vault, causing injury to the workers inside.

Condenser Pits

A common confined space found in the construction of nuclear power plants is the condenser pit. Because of their large size, they are often overlooked as potentially hazardous confined spaces. These below-grade areas create large containment areas for the accumulation of toxic fumes, gases, and so forth, or for the creation of oxygen-deficient atmospheres when purging with argon, Freon, and other inert gases. Other hazards will be created by workers above dropping equipment, tools, and materials into the pit.

Manholes

Throughout the construction site, manholes are commonplace. As means of entry into and exit from vaults, tanks, pits, and so forth, manholes perform a necessary function. However, these confined spaces may present serious hazards which could cause injuries and fatalities. A variety of hazards are associated with manholes. To begin with, the manhole could be a dangerous trap into which the worker could fall. Often covers are removed and not replaced, or else they are not provided in the first place.

Pipe Assemblies

One of the most frequently unrecognized types of confined spaces encountered throughout the construction site is the pipe assembly. Piping of sixteen to thirty-six inches in diameter is commonly used for a variety of purposes.

For any number of reasons, workers will enter the pipe. Once inside, they are faced with potential oxygen-deficient atmospheres, often caused by purging with argon or another inert gas. Welding fumes generated by the worker in the pipe, or by other workers operating outside the pipe at either end, subject the worker to toxic atmospheres.

The generally restricted dimensions of the pipe provide little room for the workers to move about and gain any degree of comfort while performing their tasks. Once inside the pipe, communication is extremely difficult. In situations where the pipe bends, communication and extrication become even more difficult. Electrical shock is another problem to which the worker is exposed.

Ungrounded tools and equipment or inadequate line cords are some of the causes. As well, heat within the pipe run may cause the worker to suffer heat prostration.

Ventilation Ducts

Ventilation ducts, like pipe runs, are very common at the construction site. These sheet metal enclosures create a complex network which moves heated and cooled air and exhaust fumes to desired locations in the plant.

Ventilation ducts may require that workers enter them to cut out access holes, install essential parts of the duct, etc. Depending on where these ducts are located, oxygen deficiency could exist. They usually possess many bends, which create difficult entry and exit and which also make it difficult for workers inside the duct to communicate with those outside it. Electrical shock hazards and heat stress are other problems associated with work inside ventilation ducts.

Tanks

Tanks are another type of confined workspace commonly found in construction. They are used for a variety of purposes, including the storage of water, chemicals, etc.

Tanks require entry for cleaning and repairs. Ventilation is always a problem. Oxygen-deficient atmospheres, along with toxic and explosive atmospheres created by the substances stored in the tanks, present hazards to workers. Heat, another problem in tanks, may cause heat prostration, particularly on a hot day.

Since electrical line cords are often taken into the tank, the hazard of electrical shock is always present. The nature of the tank's structure often dictates that workers must climb ladders to reach high places on the walls of the tank.

Sumps

Sumps are commonplace. They are used as collection places for water and other liquids. Workers entering sumps may encounter an oxygen-deficient atmosphere.

Also, because of the wet nature of the sump, electrical shock hazards are present when power tools are used inside. Sumps are often poorly illuminated. Inadequate lighting may create an accident situation.

Containment Cavities

These large below-grade areas are characterized by little or no air movement. Ventilation is always a problem. In addition, the possibility of oxygen deficiency exists. As well, welding and other gases may easily collect in these areas, creating toxic atmospheres. As these structures near completion, more confined spaces will exist as rooms are built off the existing structure.

Electrical Transformers

Electrical transformers are located on the jobsite. They often contain a nitrogen purge or dry air. Before they are opened, they must be well vented by having air pumped in. Workers, particularly electricians and power plant operators, will enter these transformers through hatches on top for various work-related reasons. Testing for oxygen deficiency and for toxic atmospheres is mandatory.

Heat Sinks

These larger pit areas hold cooling water in the event that there is a problem with the pumps located at the water supply to the plant--normally a river or lake--which would prevent cooling water from reaching the reactor core.

When in the pits, workers are exposed to welding fumes and electrical hazards, particularly because water accumulates in the bottom of the sink.

Generally, it is difficult to communicate with workers in the heat sink, because the rebar in the walls of the structure deaden radio signals.



Unusual Conditions

Confined Space within a Confined Space

By the very nature of construction, situations are created which illustrate one of the most hazardous confined spaces of all--a confined space within a confined space. This situation appears as tanks within pits, pipe assemblies or vessels within pits, etc. In this situation, not only do the potential hazards associated with the outer confined space require testing, monitoring, and control, but those of the inner space also require similar procedures.

Often, only the outer space is evaluated. When workers enter the inner space, they are faced with potentially hazardous conditions. A good example of a confined space within a confined space is a vessel with a nitrogen purge inside a filtering water access pit. Workers entering the pit and/or the vessel should do so only after both spaces have been evaluated and proper control measures established.

Hazards in One Space Entering another Space

During an examination of confined spaces in construction, one often encounters situations which are not always easy to evaluate or control. For instance, a room or area which classifies as a confined space may be relatively safe for work.

However, access passages from other areas outside or adjacent to the room could, at some point, allow the transfer of hazardous agents into the "safe" one. One such instance would be a pipe coming through a wall into a containment room.

Welding fumes and other toxic materials generated in one room may easily travel through the pipe into another area, causing it to change from a safe to an unsafe workplace. A serious problem with a situation such as this is that workers working in the "safe" area are not aware of the hazards leaking into their area. Thus, they are not prepared to take action to avoid or control it.

Session Conclusion

In this discussion, we have defined inherent and induced hazards in confined spaces. We have examined typical confined spaces on construction sites and we have described representative hazards within these confined spaces.

Permitted Confined Space Entry Program

Definition of Confined Spaces Requiring an Entry Permit

Confined space:

- ✓ Is large enough or so configured that an employee can bodily enter and perform work.
- ✓ Has limited or restricted means for entry or exit (i.e. tanks, vessels, silos, storage bins, hoppers, vaults, and pits are spaces that may have limited means of entry).
- ✓ Is not designed for continuous employee occupancy.

Purpose

The Permit Required Space (PRCS) Program is provided to protect authorized employees that will enter confined spaces and may be exposed to hazardous atmospheres, engulfment in materials, conditions which may trap or asphyxiate due to converging or sloping walls, or contains any other safety or health hazards.



Many workplaces contain confined spaces not designed for human occupancy which due to their configuration hinder employee activities including entry, work and exit. Asphyxiation is the leading cause of death in confined spaces.

Subpart P applies to all open excavations in the earth's surface.

- ✓ All trenches are excavations.
- ✓ All excavations are not trenches.

Permit Required Confined Space Entry General Rules

During all confined space entries, the following safety rules must be strictly enforced:

1. Only authorized and trained employees may enter a confined space or act as safety watchmen/attendants.
2. No smoking is permitted in a confined space or near entrance/exit area.
3. During confined space entries, a watchmen or attendant must be present at all times.
4. Constant visual or voice communication will be maintained between the safety watchmen and employees entering a confined space.
5. No bottom or side entry will be made or work conducted below the level any hanging material or material which could cause engulfment.
6. Air and oxygen monitoring is required before entering any permit-required confined space. Oxygen levels in a confined space must be between 19.5 and 23.5 percent. Levels above or below will require the use of an SCBA or other approved air supplied respirator. Additional ventilation and oxygen level monitoring is required when welding is performed. The monitoring will check oxygen levels, explosive gas levels and carbon monoxide levels. Entry will not be permitted if explosive gas is detected above one-half the Lower Explosive Limit (**LEL**).
7. To prevent injuries to others, all openings to confined spaces will be protected by a barricade when covers are removed.

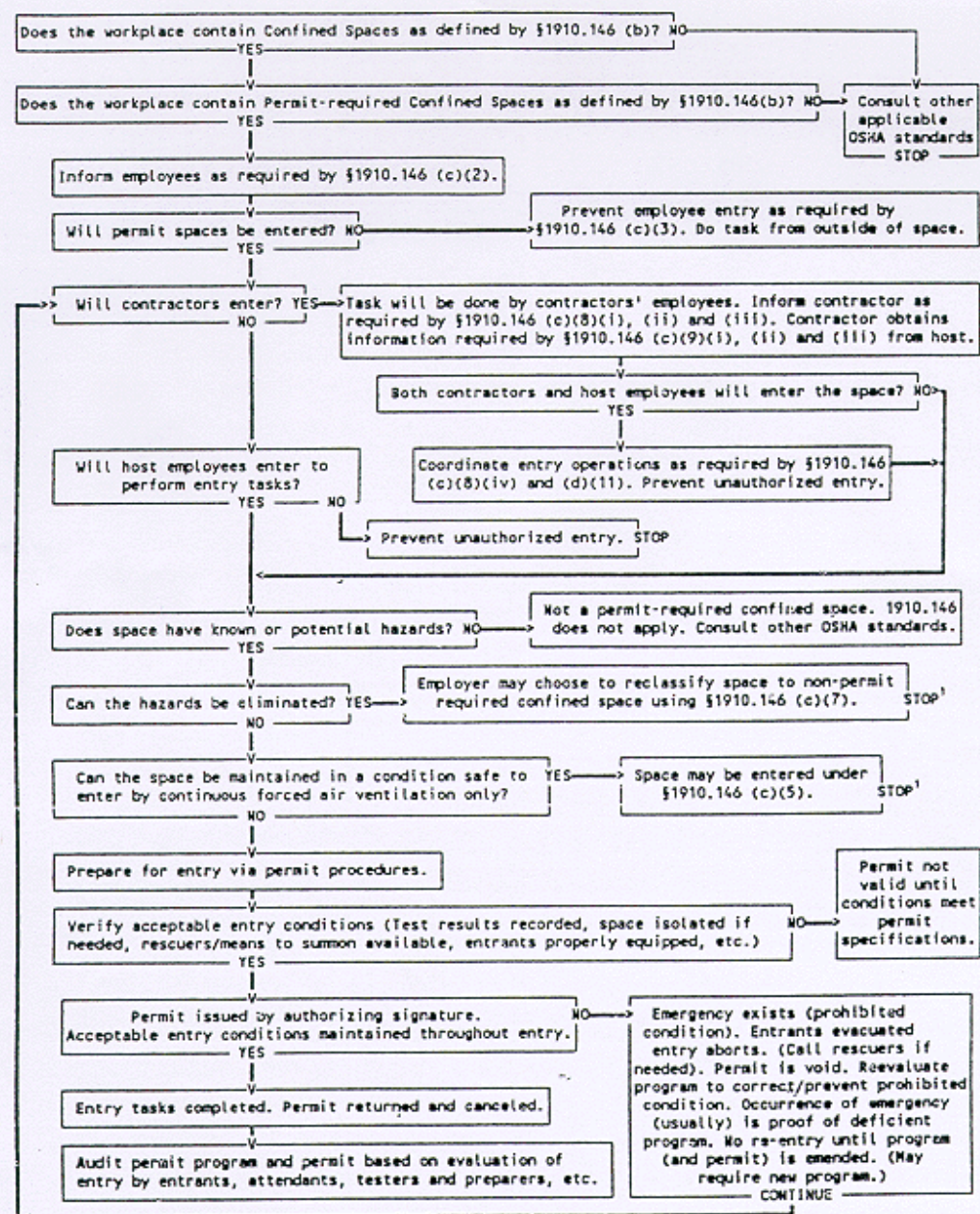


Appendix A to §1910.146

Permit-Required Confined Space Decision Flow Chart

Note: Appendices A through F serve to provide information and non-mandatory guidelines to assist employers and employees in complying with the appropriate requirements of this section.

APPENDIX A TO §1910.146—PERMIT-REQUIRED CONFINED SPACE DECISION FLOW CHART



¹ Spaces may have to be evacuated and re-evaluated if hazards arise during entry

[58 FR 4549, Jan. 14, 1993; 58 FR 34846, June 29, 1993; 63 FR 66039, Dec. 1, 1998]



Here is a small clip-on style multi-purpose gas meter. We tied a string to lower the meter in the confined space to get a gas reading before entering.



Confined Space Entry Permit *Example*

Date & Time Issued		Date & time Expires	
Space I.D.		Supervisor	
Equipment Affected		Task	
Standby Team			
Pre-Entry Atmospheric Checks	Time (am - pm)		
	Oxygen		
	Explosive (% LEL)		
	Toxic (PPM)		
	Testers Signature		
Pre-entry Fluid System Isolation		Yes	No
Pumps /lines blinded, blocked, disconnected			
Ventilation Source Established			
Mechanical Forced Air			
Natural Ventilation			
Post Ventilation Pre-Entry Atmospheric Checks			
Time			
Oxygen (%)			
Explosive (% LEL			
Toxic (PPM)			
Tester Signature			
Communication Procedures Established per specific Confined Space SOP			
Rescue Procedures established per specific Confined Space SOP			

Training Verification - for the following persons & space to be entered					YES	NO	
All persons entering Confined Space							
All persons acting as Supervisor for the Entry							
All persons assigned backup positions							
All persons assigned to monitor access and interior activities							
All persons assigned to emergency rescue team							
Equipment on Scene	YES	NO	NA		YES	NO	NA
Gas Monitor				Life Line			
Safety Harness				Hoisting Equipment			
Fall Arrest Gear				Powered Comm Eq.			
SCBAs				Air Line Respirators			
Protective Clothing				Elect Gear Properly Rated			
Periodic Atmospheric Checks							
Time (am - pm)							
Oxygen							
Explosive (% LEL)							
Toxic (PPM)							

Testers Signature				
-------------------	--	--	--	--

A review of the work authorized by this permit and the information contained on this Entry Permit. Written instructions and safety procedures have been received and are understood. Entry cannot be approved if any squares are marked in the "No" column. This permit is not valid unless all appropriate items are completed.

Permit Prepared By: (Supervisor) _____

Approved By: (Unit Supervisor) _____

This permit to be kept at job site.

Return job site copy to Safety Office following job completion.

Copies: Safety Office, Unit Supervisor, Job site

Confined Space Duties & Responsibilities

Examples of Assignments

Employees

- Follow program requirements.
- Report any previously un-identified hazards associated with confined spaces.
- Do not enter any confined spaces that have not been evaluated for safety concerns.

Management

- Provide annual Confined Space training to all employees that may need confined space training.
- Ensure confined space assessments have been conducted.
- Annually review this program and all Entry Permits.

Rescue or Training Department

- Ensure proper training for entry & rescue teams.
- Provide proper equipment for entry & rescue teams.
- Ensure all permit required confined spaces are posted.
- Evaluate rescue teams and service to ensure they are adequately trained and prepared.
- Ensure rescue team at access during entry into spaces with Immediately Dangerous to Life or Health (IDLH) atmospheres.
- Provide annual confined space awareness training to all employees that may need confined space awareness training.

Entry Supervisor

Entry supervisors are responsible for the overall permit space entry and must coordinate all entry procedures, tests, permits, equipment and other relevant activities.

The following entry supervisor duties are required:

Know the hazards that may be faced during entry, including information on the mode, signs or symptoms, and consequences of the exposure.

Verify by checking that the appropriate entries have been made on the permit, all tests specified by the permit have been conducted, and that all procedures and equipment specified by the permit are in place before endorsing the permit and allowing entry to begin.

Terminate the entry and cancel the permit when the entry is complete or there is a need for terminating the permit.

Verify that rescue services are available and that the means for summoning them are operable.

Remove unauthorized persons who enter or attempt to enter the space during entry operations.



Determine whenever responsibility for a permit space entry operation is transferred and at intervals dictated by the hazards and operations performed within the space that entry operations remain consistent with the permit terms and that acceptable entry conditions are maintained.

Entry Attendants

At least one attendant is required outside the permit space into which entry is authorized for the duration of the entry operation. Responsibilities include:

- To know the hazards that may be faced during entry, including information on the mode, signs or symptoms, and consequences of the exposure.
- To be aware of possible behavioral effects of hazard exposure on entrants.
- To continuously maintain an accurate count of entrants in the permit space and ensures a means to accurately identify authorized entrants.
- To remain outside the permit space during entry operations until relieved by another attendant (once properly relieved, they may participate in other permit space activities, including rescue if they are properly trained and equipped).
- To communicate with entrants as necessary to monitor entrant status and alert entrants of the need to evacuate.
- To monitor activities inside and outside the space to determine if it is safe for entrants to remain in the space; orders the entrants to immediately evacuate if: the attendant detects a prohibited condition, detects entrant behavioral effects of hazard exposure, detects a situation outside the space that could endanger the entrants; or if the attendant cannot effectively and safely perform all the attendant duties.
- To summon rescue and other emergency services as soon as the attendant determines the entrants need assistance to escape the permit space hazards.
- To perform non-entry rescues as specified by that rescue procedure and entry supervisor and not to perform duties that might interfere with the attendants' primary duty to monitor and protect the entrants.

Entering a Confined Space



This space requires an emergency retrieval system, continuous air monitoring, and safety watch or two-way communication for safe entry.



Donning the personal protective equipment (**PPE**) necessary for confined space entry.

The full-body harness provides fully adjustable leg and shoulder straps for worker comfort and proper fit.

Stamped steel sliding back D-ring and subpelvic strap provide optimum force distribution.



Example of a "**D-Ring**" and fall protection harness used when entering a confined space. The D-Ring provides a compatible anchor point for connecting devices such as lanyards or retractable lifelines.

The shock absorbing lanyard provides a deceleration distance during a fall to reduce fall arrest forces for extra protection against injury.



Tripod-retrieval assembly in use for an entry into one of the many confined spaces.



Checking the cable tension and inertial locking mechanism of the retrieval assembly.

Correct use of this device prevents free-falls greater than 2 feet.



The entrant descends into the space as the attendant critiques the operation.



Dramatic rescue simulation using the tripod-retrieval system.



The entrant is now safely out of the space and is ready to return to his many other projects after this simulated exercise.

Duties of the Person Authorizing or in Charge of the Entry

The person who authorizes or is in charge of the permit entry confined space must comply with the following:

1. Make certain that all pre-entry requirements as outlined on the permit have been completed before any worker is allowed to enter the confined space.
2. Make certain that any required pre-entry conditions are present.
3. If an in-plant/facility rescue team is to be used in the event of an emergency, make sure they would be available. If your Employer does not maintain an in-plant rescue team, dial 911 on any telephone for the Rescue Squad.
4. Make sure that any communication equipment which would be used to summon either the in-plant rescue team or other emergency assistance is operating correctly.
5. Terminate the entry upon becoming aware of a condition or set of conditions whose hazard potential exceeds the limits authorized by the entry permit.

If the person who would otherwise issue an entry permit is in charge of the entry and present during the entire entry, then a written permit is not required if that person uses a checklist as provided in the section on "**Permits**".

This person may also serve as the attendant at the site.

Special Considerations During A Permit Required Entry

Certain work being performed in a permit entry confined space could cause the atmosphere in the space to change. Examples of this are welding, drilling, or sludge removal. In these situations, air monitoring of the confined space should be conducted on a continuous basis throughout the time of the entry.

If the workers leave the confined space for any significant period of time, such as for a lunch or other break, the atmosphere of the confined space must be retested before the workers reenter the confined space.

Unauthorized Persons

Take the following actions when unauthorized persons approach or enter a permit space while entry is under way:

1. Warn the unauthorized persons that they must stay away from the permit space,
2. Advise unauthorized persons that they must exit immediately if they have entered the space, and
3. Inform the authorized entrants and the entry supervisor if unauthorized persons have entered the permit space.

Entrants

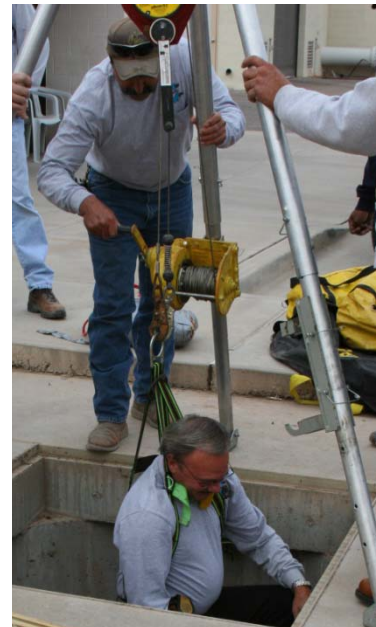
All entrants must be authorized by the entry supervisor to enter permit spaces, have received the required training, have used the proper equipment, and observed the entry procedures and permit requirements.

The following entrant duties are required:

Know the hazards that may be faced during entry, including information on the mode, signs or symptoms, and consequences of the exposure;

Properly use the equipment required for safe entry;

Communicate with the attendant as necessary to enable the attendant to monitor the status of the entrants and to enable the attendant to alert the entrants of the need to evacuate the space if necessary;



Alert the attendant whenever; the entrant recognizes any warning signs or symptoms of exposure to a dangerous situation, or any prohibited condition is detected; and Exit the permit space as quickly as possible whenever the attendant or entry supervisor gives an order to evacuate the permit space, the entrant recognizes any warning signs or symptoms of exposure to a dangerous situation, the entrant detects a prohibited condition, or an evacuation alarm is activated.



Normal day for a pretreatment inspector. Get used to hydrogen sulfide gas because you will smell, and taste it the rest of your life.

Hazards

- ✓ Explosive / Flammable Atmospheres
- ✓ Toxic Atmospheres
- ✓ Engulfment
- ✓ Asphyxiation
- ✓ Entrapment
- ✓ Slips & falls
- ✓ Chemical Exposure
- ✓ Electric Shock
- ✓ Thermal / Chemical Burns
- ✓ Noise & Vibration



Hazard Control

Engineering Controls

- Locked entry points
- Temporary ventilation
- Temporary Lighting

Administrative Controls

- Signs
- Employee training
- Entry procedures
- Atmospheric Monitoring
- Rescue procedures
- Use of prescribed Personal Protective Equipment

Entry Standard Operating Procedures

This program outlines:

- Hazards
- Hazard Control & Abatement
- Acceptable Entry Conditions
- Means of Entry
- Entry Equipment Required
- Emergency Procedures



Permit Required Confined Space Entry General Rules

During all confined space entries, the following safety rules must be strictly enforced:

1. Only authorized and trained employees may enter a confined space or act as safety watchman/attendant.
2. No smoking is permitted in a confined space or near entrance/exit area.
3. During confined space entries, a watchman must be present at all times.
4. Constant visual or voice communication will be maintained between the safety watchman/attendant and employees entering a confined space.
5. No bottom or side entry will be made or work conducted below the level of any hanging material or material which could cause engulfment.
6. Air and oxygen monitoring is required before entering any permit-required confined space. Oxygen levels in a confined space must be between 19.5 and 23.5 percent. Levels above or below will require the use of an SCBA or other approved air supplied respirator. Additional ventilation and oxygen level monitoring is required when welding is performed.

The monitoring will check oxygen levels, explosive gas levels and carbon monoxide levels. Entry will not be permitted if explosive gas is detected above one-half the Lower Explosive Limit (LEL), or 10% of a specific gas explosive limit.

7. To prevent injuries to others, all openings to confined spaces will be protected by a barricade when covers are removed.

Confined Space Entry Procedures

Each employee who enters or is involved in the entry must:

1. Understand the procedures for confined space entry
2. Know the Hazards of the specific space
3. Review the specific procedures for each entry
4. Understand how to use entry and rescue equipment

Confined Space Entry Permits

Confined Space Entry Permits must be completed before any employee enters a permit-required confined space. The permit must be completed and signed by an authorized member of management before entry.

Permits will expire before the completion of the shift or if any pre-entry conditions change. Permits will be maintained on file for 12 months.



Contractor Entry

All work by non-company employees that involves the entry into confined spaces will follow the procedures of this program. The information of this program and specific hazards of the confined spaces to be entered will be provided to contractor management prior to commencing entry or work.

**Important Rescue Service Questions**

What is the availability of the rescue service?

Is it unavailable at certain times of the day or in certain situations?

What is the likelihood that key personnel of the rescue service might be unavailable at times?

If the rescue service becomes unavailable while an entry is underway, does it have the capability of notifying the employer so that the employer can instruct the attendant to abort the entry immediately?

Confined Space Training

Training for Confined Space Entry includes:

1. Duties of entry supervisor, entrant and attendants
2. Confined space entry permits
3. Hazards of confined spaces
4. Use of air monitoring equipment
5. First aid and CPR training
6. Emergency action & rescue procedures
7. Confined space entry & rescue equipment
8. Rescue training, including entry and removal from representative spaces

Confined Space Training and Education

OSHA's General Industry Regulation, §1910.146 Permit-required confined spaces, contains requirements for practices and procedures to protect employees in general industry from the hazards of entry into permit-required confined spaces. This regulation does not apply to construction.

OSHA's Construction Safety and Health Regulations Part 1926 do not contain a permit-required confined space regulation. Subpart C, §1926.21 Safety training and education specifies training for personnel who are required to enter confined spaces and defines a "**confined or enclosed space**." These requirements are shown below.

§1926.21 Safety training and education. (Partial)

(b)(6)(i) All employees required to enter into confined or enclosed spaces shall be instructed as to the nature of the hazards involved, the necessary precautions to be taken, and in the use of protective and emergency equipment required. The employer shall comply with any specific regulations that apply to work in dangerous or potentially dangerous areas.

(ii) For purposes of paragraph (b)(6)(i) of this section, "**confined or enclosed space**" means any space having a limited means of egress, which is subject to the accumulation of toxic or flammable contaminants or has an oxygen deficient atmosphere. Confined or enclosed spaces include, but are not limited to, storage tanks, process vessels, bins, boilers, ventilation or exhaust ducts, sewers, underground utility vaults, tunnels pipelines, and open top spaces more than 4 feet in depth such as pits, tubs, vaults, and vessels.

OSHA's Construction Regulations also contain requirements dealing with confined space hazards in underground construction (Subpart S), underground electric transmission and distribution work (§1926.956), excavations (Subpart P), and welding and cutting (Subpart J).

Further guidance may be obtained from American National Standard ANSI Z117.1-1989, Safety Requirements for Confined Spaces. This standard provides minimum safety requirements to be followed while entering, exiting and working in confined spaces at normal atmospheric pressure. This standard does not pertain to underground mining, tunneling, caisson work or other similar tasks that have established national consensus standards.

Your Employer is Responsible for Certain Training Requirements

These are as follows:

1. **GENERAL** As an employer, your employer must ensure that all workers who must enter a permit entry confined space in the course of their work are informed of appropriate procedures and controls for entry into such spaces. These workers must be made aware of the fact that an unauthorized entry could be fatal, and that their senses are unable to detect and evaluate the severity of atmospheric hazards.

2. TRAINING FOR AUTHORIZED ENTRANTS Your employer must ensure that all authorized entrants know the emergency action plan and have received training covering the following subjects prior to entering any permit entry confined space:

a. **Hazard Recognition:** Each worker must understand the nature of the hazard before entering and the need to perform appropriate testing to determine if it is safe to enter.

b. **Use of Personal Protective Equipment:** Each employee must be taught the proper use of all personal protective equipment required for entry or rescue, and the proper use of protective barriers and shields.

c. **Self-Rescue:** Each worker must be trained to get out of the confined space as rapidly as possible without help whenever an order to evacuate is given by the attendant, whenever an automatic evacuation alarm is activated, or whenever workers recognize the warning signs of exposure to substances that could be found in the confined space. They must also be made aware of the toxic effects or symptoms of exposure to hazardous materials he could encounter in the confined space. This includes anything that could be absorbed through the skin or which could be carried through the skin by any solvents that are used. They must be trained to relay an alarm to the attendant and to attempt self-rescue immediately upon becoming aware of these effects.

d. **Special Work Practices or Procedures:** Each worker must be trained in any modifications of normal work practices that are necessary for permit entry confined space work.

3. TRAINING FOR PERSONS AUTHORIZING OR IN CHARGE OF ENTRY In addition to other requirements already covered, the person authorizing or in charge of entry shall be trained to recognize the effects of exposure to hazards that could be in the confined space. They must also carry out all duties that the permit assigns to them.



Rescue practice training. In the photo above, the sand bag represents a fallen victim.

4. TRAINING FOR ATTENDANT Any worker functioning as an attendant at a permit entry confined space must be trained in the company's emergency action plan, the duties of the attendant, and in;

- a. Proper use of the communications equipment furnished for communicating with authorized workers entering the confined space or for summoning emergency or rescue services.
- b. Authorized procedures for summoning rescue or other emergency services.
- c. Recognition of the unusual actions of a worker which could indicate that they could be experiencing a toxic reaction to contaminants that could be present in the space.
- d. Any training for rescuers, if the attendant will function as a rescuer also.
- e. Any training for workers who enter the confined space, if the permit specifies that the duty of the attendant will rotate among the workers authorized to enter the confined space.



CONFINED SPACE AUTHORIZED ENTRANT'S LOG EXAMPLE

CONFINED SPACE:
TIME:

DATE:

ENTRANT'S NAME (PRINT)	TIME IN	TIME OUT

ENTRY Attendant:

ENTRY Supervisor Review:



What do you think? Is this a dangerous confined space?

Would you weld inside a large pipe all alone? I am sure he is paid well, but is he safe and sound?

Confined Space Entry Procedure

Space _____ Date Last Modified _____

Place check mark in all applicable areas

Hazards		Personal Protective Equipment	
☐	Explosive / Combustion Hazard	☐	Air supplied Respirator
☐	Exposed Electrical Circuits	☐	Air Purifying Respirator
☐	Unguarded Machine Parts	☐	Welding Protection
☐	Atmospheric Hazard	☐	Gloves
☐	Potential Atmospheric Hazard	☐	Hard Hat
☐	Thermal Hazard	Ventilation Requirements	
☐	Chemical Hazard	☐	Continuous ____cuft/min Note: See Ventilation Guidelines for Confined Spaces for typical ventilation configurations and formulas.
☐	Fall Hazard	☐	
☐	Engulfment hazard	Note: Additional ventilation may be required for hot work, grinding or other operations that would produce airborne fumes, mist or dust. Entry Supervisor must assess additional ventilation requirements base on tasks to be performed in the space	
☐	Converging Walls	☐	
☐	Floors slope-small cross-section	☐	
☐	Slip Hazard	☐	
Entry Path		☐	Vent Exhaust Point:
☐	Side entry	☐	Vent Supply Point:
☐	Bottom entry	☐	Space Volume
☐	Door	☐	Initial Purge Time= $\frac{7.5 \times (\text{space volume})}{\text{Effective Blower Capacity}}$
☐	Top open entry	☐	
☐	Top manhole entry	☐	20 Air Changes per Hour (ACH) for duration of entry
☐	Hinged hatch	☐	Minimum initial Purge Time= 20 Minutes

Entry & Rescue Equipment		Adequate Blower Capacity (ABC) = _____ ABC = $\frac{\text{Space Volume} \times 20 \text{ ACH}}{60 \text{ minutes}}$	
	Life Line		
	Floor level opening barrier	Acceptable Entry Conditions	
	Body Harness		Confined Space Entry permit posted
	Tripod		Oxygen 19.5 23.5%
	Man Winch		Lower Explosive Level %
	Fall Arrest Unit		Toxic fumes/vapors Less than PEL
	Emerg Retrieval Line		No engulfing material in space
	Atmospheric Monitor		No hazardous chemicals or material
	Blower /Saddle / Trunks		Drained - Flushed
	Drop Light		Rescue Team Available on Site
	Communication Gear		Ventilation Established & Maintained
	Ladder		LOTO Electrical components in space
	Hand held radios		LOTO Mechanical Components in space
	Portable Lighting		LOTO All pipes to and from space



Other Hazards

Flammable Atmospheres

A flammable atmosphere generally arises from enriched oxygen atmospheres, vaporization of flammable liquids, byproducts of work, chemical reactions, concentrations of combustible dusts, and desorption of chemical from inner surfaces of the confined space.

An atmosphere becomes flammable when the ratio of oxygen to combustible material in the air is neither too rich nor too lean for combustion to occur. Combustible gases or vapors will accumulate when there is inadequate ventilation in areas such as a confined space.

Flammable gases such as acetylene, butane, propane, hydrogen, methane, natural or manufactured gases or vapors from liquid hydrocarbons can be trapped in confined spaces, and since many gases are heavier than air, they will seek lower levels as in pits, sewers, and various types of storage tanks and vessels. In a closed top tank, it should also be noted that lighter than air gases may rise and develop a flammable concentration if trapped above the opening.

The byproducts of work procedures can generate flammable or explosive conditions within a confined space. Specific kinds of work such as spray painting can result in the release of explosive gases or vapors. Welding in a confined space is a major cause of explosions in areas that contain combustible gas.

Chemical reactions forming flammable atmospheres occur when surfaces are initially exposed to the atmosphere, or when chemicals combine to form flammable gases. This condition arises when dilute sulfuric acid reacts with iron to form hydrogen or when calcium carbide makes contact with water to form acetylene.

Other examples of spontaneous chemical reactions that may produce explosions from small amounts of unstable compounds are acetylene-metal compounds, peroxides, and nitrates. In a dry state, these compounds have the potential to explode upon percussion or exposure to increased temperature.

Another class of chemical reactions that form flammable atmospheres arise from deposits of pyrophoric substances (carbon, ferrous oxide, ferrous sulfate, iron, etc.) that can be found in tanks used by the chemical and petroleum industry. These tanks containing flammable deposits will spontaneously ignite upon exposure to air.

Combustible dust concentrations are usually found during the process of loading, unloading, and conveying grain products, nitrated fertilizers, finely ground chemical products, and any other combustible material.

High charges of static electricity, which rapidly accumulate during periods of relatively low humidity (below 50%) can cause certain substances to accumulate electrostatic charges of sufficient energy to produce sparks and ignite a flammable atmosphere. These sparks may also cause explosions when the right air or oxygen to dust or gas mixture is present.

Toxic Atmospheres

The substances to be regarded as toxic in a confined space can cover the entire spectrum of gases, vapors, and finely-divided airborne dust in industry. The sources of toxic atmospheres encountered may arise from the following:

1. The manufacturing process (for example, in producing polyvinyl chloride, hydrogen chloride is used as well as vinyl chloride monomer, which is carcinogenic).
2. The product stored [removing decomposed organic material from a tank can liberate toxic substances, such as hydrogen sulfide (H_2S)].
3. The operation performed in the confined space (for example, welding or brazing with metals capable of producing toxic fumes).

During loading, unloading, formulation, and production, mechanical and/or human error may also produce toxic gases which are not part of the planned operation.

Carbon monoxide (**CO**) is a hazardous gas that may build up in a confined space. This odorless, colorless gas that has approximately the same density as air is formed from incomplete combustion of organic materials such as wood, coal, gas, oil, and gasoline; it can be formed from microbial decomposition of organic matter in sewers, silos, and fermentation tanks.

CO is an insidious toxic gas because of its poor warning properties. Early stages of CO intoxication are nausea and headache. CO may be fatal at as little as 1000 ppm or 10% in air, and is considered dangerous at 200 ppm or 2%, because it forms Carboxyhemoglobin in the blood which prevents the distribution of oxygen in the body.

CO is a relatively abundant colorless, odorless gas. Therefore, any untested atmosphere must be suspect. It must also be noted that a safe reading on a combustible gas indicator does not ensure that CO is not present. CO must be tested for specifically. The formation of CO may result from chemical reactions or work activities, therefore fatalities due to CO poisoning are not confined to any particular industry. There have been fatal accidents in sewage treatment plants due to decomposition products and lack of ventilation in confined spaces.

Another area where CO results as a product of decomposition is in the formation of silo gas in grain storage elevators. In another area, the paint industry, varnish is manufactured by introducing the various ingredients into a kettle, and heating them in an inert atmosphere, usually town gas, which is a mixture of carbon dioxide and nitrogen.

In welding operations, oxides of nitrogen and ozone are gases of major toxicologic importance, and incomplete oxidation may occur and carbon monoxide can form as a byproduct. Another poor work practice, which has led to fatalities, is the recirculation of diesel exhaust emissions. Increased CO levels can be prevented by strict control of the ventilation and the use of catalytic converters.

Procedures for Atmospheric Testing. - 1910.146 App B

OSHA Requirement

Subpart Title: General Environmental Controls

Atmospheric testing is required for two distinct purposes:

evaluation of the hazards of the permit space and verification that acceptable entry conditions for entry into that space exist.

(1) Evaluation testing. The atmosphere of a confined space should be analyzed using equipment of sufficient sensitivity and specificity to identify and evaluate any hazardous atmospheres that may exist or arise, so that appropriate permit entry procedures can be developed and acceptable entry conditions stipulated for that space.

Evaluation and interpretation of these data, and development of the entry procedure, should be done by, or reviewed by, a technically qualified professional (e.g., OSHA consultation service, or certified industrial hygienist, registered safety engineer, certified safety professional, certified marine chemist, etc.) based on evaluation of all serious hazards.

(2) Verification testing. The atmosphere of a permit space which may contain a hazardous atmosphere should be tested for residues of all contaminants identified by evaluation testing using permit specified equipment to determine that residual concentrations at the time of testing and entry are within the range of acceptable entry conditions. Results of testing (i.e., actual concentration, etc.) should be recorded on the permit in the space provided adjacent to the stipulated acceptable entry condition.

(3) Duration of testing. Measurement of values for each atmospheric parameter should be made for at least the minimum response time of the test instrument specified by the manufacturer.

(4) Testing stratified atmospheres. When monitoring for entries involving a descent into atmospheres that may be stratified, the atmospheric envelope should be tested a distance of approximately 4 feet (1.22 m) in the direction of travel and to each side. If a sampling probe is used, the entrant's rate of progress should be slowed to accommodate the sampling speed and detector response.

(5) Order of testing. A test for oxygen is performed first because most combustible gas meters are oxygen dependent and will not provide reliable readings in an oxygen deficient atmosphere.

Combustible gases are tested for next because the threat of fire or explosion is both more immediate and more life threatening, in most cases, than exposure to toxic gases and vapors. If tests for toxic gases and vapors are necessary, they are performed last.



This is a ten-minute escape air pack or emergency air supply. The plastic bag will go over your head during an emergency and provide enough air to get out of the hole. There are smaller versions of this system.

Confined Space Program *Multi-gas Meter Instructions*

Functional Buttons:



On/Off	Press black button and hold until display tells you to RELEASE. Turn on in a clean-air environment.
Mode	Press "mode" button at display prompt.
E Button	Press (E) button at display prompt.
Alarm Mode	Red lights flash and unit beeps. Beeps are more frequent at higher contaminant levels, or lower oxygen level.



Forced air ventilation with a disposable air shaft.

Typical Display of the TMX412

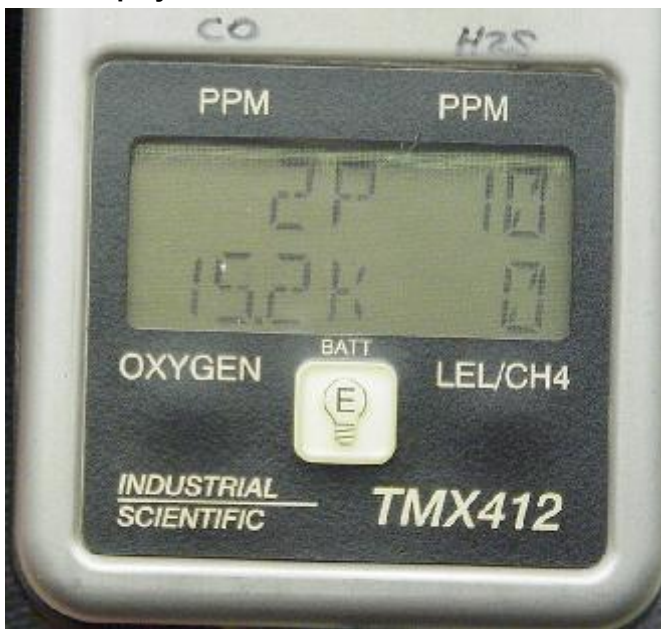


Location of gases on display.



Example of a clean air display. Carbon monoxide (**CO**) and hydrogen sulfide (**H₂S**) are in ppm; oxygen (**O₂**) and lower explosive limit (**LEL**) readings are percentage values. The battery-life indicator is just right of the oxygen display (i.e., 20.9); each line represents about one hour of service remaining.

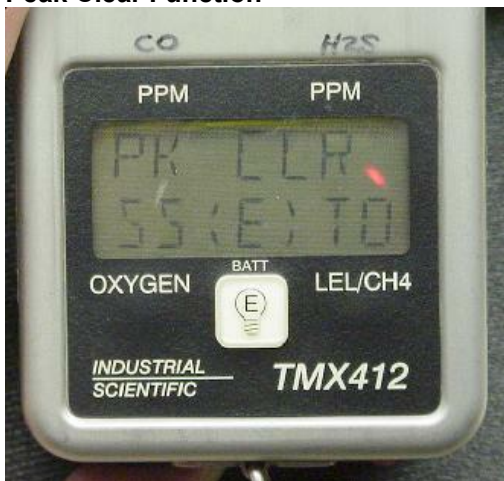
Peak Display Function



Example Display for Peak Mode: The display reads 2 ppm peak value for CO and 10 ppm peak value for H₂S (top line); 15.2 % for oxygen and 0 % for LEL (bottom line).

- Use the PEAK function to display highest recorded readings for CO, H₂S, and LEL, and the lowest reading for O₂.
- Readings are not erased when you turn the unit off. You must use the PEAK CLEAR function to erase the memory.
- Make sure you check the peak readings have been cleared before you start your monitoring session.
- Press mode button until display reads "P" (top line), and "K" (bottom line) (see photo).

Peak Clear Function



- Use the **PEAK CLEAR** function to clear peak readings from the internal memory. Readings are not erased when you turn the unit off. You must use the **PEAK CLEAR** function to erase the memory.
- Press mode button until display reads "PK CLR PRESS (E) TO RESET". After you press the (E) button, press mode button again until peak reading appears. Unit should now read 0,0 (top line), and 21, 0 (bottom line) assuming this was performed in a clean-air environment.

Zero Function and Calibration Function:

- Zero and Calibration Functions are performed by Attendant or as specified by the Supervisor or manufacturer.
- Special equipment and experience is necessary to properly perform these functions.

Documentation and Training:

- Make sure you are familiar with all of our confined space entry equipment, including the multi-gas monitor, before use.
- Make sure to document your air monitoring data (e.g., peak values and other relevant data) on the Confined Space Air Monitoring Data Form.



You need continued atmospheric monitoring during the entry in any confined space. Most entrants will carry two gas monitors for increased safety.

Atmospheric Testing Policy *Example*

Before entry, it is necessary to test the atmosphere in the confined space for oxygen levels, flammability, and/or any contaminants that have a potential to be present in that confined space. This testing must be done by a qualified person using equipment which has been approved for use in such areas.

The testing equipment itself should be checked to make sure it is working properly before using it. Follow the manufacturer's recommended procedures.

Testing of the confined spaces should be conducted throughout the entire portion of the space that workers will occupy during the entry. This testing shall be done without the use of ventilation systems.

Where the entry is vertical into the confined space, it is recommended that remote probes be used to measure the atmosphere at various levels. This is necessary because some gases and vapors are lighter or heavier than air and can accumulate at different levels in the confined space. Test outside the confined space to make sure the surrounding air is not contaminated.

Atmospheric conditions are considered unacceptable if oxygen levels are less than 19.5% or greater than 23.5%. Regulations define the following unacceptable levels of other hazards monitored:

1. A flammable gas, vapor or mist greater than 10% of its lower flammable limit (**LFL**). LFL means the minimum concentration of the flammable material which will ignite if an ignition source is present.
2. An airborne combustible dust at a concentration that obscures vision at a distance of five feet or less.
3. An atmospheric concentration of a substance greater than the allowed limit in the Material Safety Data Sheet for that substance.

If test results conclude that the atmospheric condition of the confined space is unacceptable, entry is prohibited until such conditions are brought into acceptable limits. This may be done by purging, cleaning and/or ventilating the space. Purging refers to the method by which gases, vapors, or other airborne impurities are displaced from a confined space.



The confined space may also be made non-flammable, non-explosive or otherwise chemically non-reactive by displacing or diluting the original atmosphere with steam or gas that is non-reactive with respect to that space, a process referred to as "***inerting***".

Irritant (Corrosive) Atmospheres

Irritant or corrosive atmospheres can be divided into primary and secondary groups. The primary irritants exert no systemic toxic effects (effects on the entire body).

Examples of primary irritants are chlorine, ozone, hydrochloric acid, hydrofluoric acid, sulfuric acid, nitrogen dioxide, ammonia, and sulfur dioxide. A secondary irritant is one that may produce systemic toxic effects in addition to surface irritation. Examples of secondary irritants include benzene, carbon tetrachloride, ethyl chloride, trichloroethane, trichloroethylene, and chloropropene.

Irritant gases vary widely among all areas of industrial activity. They can be found in plastics plants, chemical plants, the petroleum industry, tanneries, refrigeration industries, paint manufacturing, and mining operations. Prolonged exposure at irritant or corrosive concentrations in a confined space may produce little or no evidence of irritation. This may result in a general weakening of the defense reflexes from changes in sensitivity. The danger in this situation is that the worker is usually not aware of any increase in his/her exposure to toxic substances.

Asphyxiating Atmospheres

The normal atmosphere is composed approximately of 20.9% oxygen and 78.1% nitrogen, and 1% argon with small amounts of various other gases. Reduction of oxygen in a confined space may be the result of either consumption or displacement.

The consumption of oxygen takes place during combustion of flammable substances, as in welding, heating, cutting, and brazing. A more subtle consumption of oxygen occurs during bacterial action, as in the fermentation process.

Oxygen may also be consumed during chemical reactions as in the formation of rust on the exposed surface of the confined space (iron oxide). The number of people working in a confined space and the amount of their physical activity will also influence the oxygen consumption rate. A second factor in oxygen deficiency is displacement by another gas. Examples of gases that are used to displace air, and therefore reduce the oxygen level are helium, argon, and nitrogen.

Carbon dioxide may also be used to displace air and can occur naturally in sewers, storage bins, wells, tunnels, wine vats, and grain elevators. Aside from the natural development of these gases, or their use in the chemical process, certain gases are also used as inerting agents to displace flammable substances and retard pyrophoric reactions.

Gases such as nitrogen, argon, helium, and carbon dioxide, are frequently referred to as non-toxic inert gases but have claimed many lives. The use of nitrogen to inert a confined space has claimed more lives than carbon dioxide. The total displacement of oxygen by nitrogen will cause immediate collapse and death.

Carbon Dioxide

Carbon dioxide and argon, with specific gravities greater than air, may lie in a tank or manhole for hours or days after opening. Since these gases are colorless and odorless, they pose an immediate hazard to health unless appropriate oxygen measurements and ventilation are adequately carried out.

Oxygen Deprivation

Oxygen deprivation is one form of asphyxiation. While it is desirable to maintain the atmospheric oxygen level at 21% by volume, the body can tolerate deviation from this ideal. When the oxygen level falls to 17%, the first sign of hypoxia is deterioration of night vision, which is not noticeable until a normal oxygen concentration is restored. Physiologic effects are increased breathing volume and accelerated heartbeat.

Between 14-16% physiologic effects are increased breathing volume, accelerated heartbeat, very poor muscular coordination, rapid fatigue, and intermittent respiration. Between 6-10% the effects are nausea, vomiting, inability to perform, and unconsciousness. Less than 6%, the effects are spasmodic breathing, convulsive movements, and death in minutes.

Mechanical Hazards

If activation of electrical or mechanical equipment would cause injury, each piece of equipment should be manually isolated to prevent inadvertent activation before workers enter or while they work in a confined space. The interplay of hazards associated with a confined space, such as the potential of flammable vapors or gases being present, and the build-up of static charge due to mechanical cleaning, such as abrasive blasting, all influence the precautions which must be taken.

To prevent vapor leaks, flashbacks, and other hazards, workers should completely isolate the space. To completely isolate a confined space, the closing of valves is not sufficient. All pipes must be physically disconnected or isolation blanks bolted in place. Other special precautions must be taken in cases where flammable liquids or vapors may re-contaminate the confined space.

The pipes blanked or disconnected should be inspected and tested for leakage to check the effectiveness of the procedure. Other areas of concern are steam valves, pressure lines, and chemical transfer pipes. A less apparent hazard is the space referred to as a void, such as double walled vessels, which must be given special consideration in blanking off and inerting.

Thermal Effects

Four factors influence the interchange of heat between people and their environment. They are: (1) air temperature, (2) air velocity, (3) moisture contained in the air, and (4) radiant heat. Because of the nature and design of most confined spaces, moisture content and radiant heat are difficult to control.

As the body temperature rises progressively, workers will continue to function until the body temperature reaches approximately 102°F.

When this body temperature is exceeded, the workers are less efficient, and are prone to heat exhaustion, heat cramps, or heat stroke. In a cold environment, certain physiologic mechanisms come into play, which tend to limit heat loss and increase heat production. The most severe strain in cold conditions is chilling of the extremities so that activity is restricted. Special precautions must be taken in cold environments to prevent frostbite, trench foot, and general hypothermia.

Protective Insulated Clothing

Protective insulated clothing for both hot and cold environments will add additional bulk to the worker and must be considered in allowing for movement in the confined space and exit time. Therefore, air temperature of the environment becomes an important consideration when evaluating working conditions in confined spaces.

Noise

Noise problems are usually intensified in confined spaces because the interior tends to cause sound to reverberate and thus expose the worker to higher sound levels than those found in an open environment.

This intensified noise increases the risk of hearing damage to workers, which could result in temporary or permanent loss of hearing. Noise in a confined space which may not be intense enough to cause hearing damage may still disrupt verbal communication with the emergency standby person on the exterior of the confined space. If the workers inside are not able to hear commands or danger signals due to excessive noise, the probability of severe accidents can increase.

Vibration

Whole body vibration may affect multiple body parts and organs, depending upon the vibration characteristics. Segmental vibration, unlike whole body vibration, appears to be more localized in creating injury to the fingers and hands of workers using tools, such as pneumatic hammers, rotary grinders or other hand tools which cause vibration.

Other Hazards

Some physical hazards cannot be eliminated because of the nature of the confined space or the work to be performed. These hazards include such items as scaffolding, surface residues, and structural hazards. The use of scaffolding in confined spaces has contributed too many accidents caused by workers or materials falling, improper use of guard rails, and lack of maintenance to insure worker safety.

The choice of material used for scaffolding depends upon the type of work to be performed, the calculated weight to be supported, and the surface on which the scaffolding is placed, as well as the substance previously stored in the confined space. Surface residues in confined spaces can increase the already hazardous conditions of electrical shock, reaction of incompatible materials, liberation of toxic substances, and bodily injury due to slips and falls. Without protective clothing, additional hazards to health may arise due to surface residues.

Structural hazards within a confined space such as baffles in horizontal tanks, trays in vertical towers, bends in tunnels, overhead structural members, or scaffolding installed for maintenance constitute physical hazards, which are exacerbated by the physical surroundings. In dealing with structural hazards, workers must review and enforce safety precautions to assure safety.



Abbreviations:

PEL - permissible exposure limit: Average concentration that must not be exceeded during 8-hour work shift of a 40-hour workweek.

STEL - Short-term exposure limit: 15-minute exposure limit that must not be exceeded during the workday.

REL - Recommended exposure limit: Average concentration limit recommended for up to a 10-hour workday during a 40-hour workweek.

IDLH - Immediately dangerous to life or health: Maximum concentration from which person could escape (in event of respirator failure) without permanent or escape-impairing effects within 30 minutes.

Required Confined Space Equipment Policy *Example*

Air Testing Equipment

All air-testing equipment should be calibrated in accordance with the manufacturer's instruction.

Oxygen Meters and Monitors

The oxygen content of the air in a confined space is the first and most important constituent to measure before entry is made. The acceptable range of oxygen is between 19.5 and 23.5 percent. This content is measured before flammability is tested because rich mixtures of flammable gases or vapors give erroneous measurement results.

For example, a mixture of 90 percent methane and 10 percent air will test nonflammable because there is not enough oxygen to support the combustion process in the flammability meters. This mixture will not support life and will soon become explosive if ventilation is provided to the space. Before entry, spaces must be ventilated until both oxygen content and flammability are acceptable.

Flammability Meters

Flammability meters are used to measure the amount of flammable vapors or gases in the atmosphere as a percent of the LEL/LFL. The oxygen content must be near 21 percent for results to be meaningful.

Toxic Air Contamination Testers

Tests for toxic contaminants must be specific for the target toxin. The instrument manufacturer should be consulted for interferences. Therefore, it is important to know the history of the confined space so proper tests can be performed. Part of hazard assessment is to identify all possible contaminants that could be in the confined space.

Protective Devices

Fall-Protection Equipment

Fall-protection equipment for confined spaces should be the chest-waist harness type to minimize injuries from uncontrolled movements when it arrests a worker's fall. This type of harness also permits easier retrieval from a confined space than a waist belt. Adjustable lanyards should be used to limit free fall to two feet before arrest.

Respirators

An industrial hygienist should select respirators on the basis of his or her evaluation of possible confined-space hazards. NIOSH-approved respirators should be identified in the approved procedure required by the confined-space entry permit. It is important to note that air-purifying respirators cannot be used in an oxygen deficient atmosphere.

Lockout/Tagout Devices

Lockout/tagout devices permit employees to work safely on de-energized equipment without fear that the devices will be accidentally removed. Lock and tag devices are required to withstand a 50-pound pull without failure. Devices used to block or restrain stored mechanical energy devices must be engineered for safety.

Safety Barriers

Safety barriers separate workers from hazards that cannot reasonably be eliminated by other engineering controls. Required barriers will be identified in the approved confined-space entry procedure.

Ground Fault Circuit Interrupters

Ground fault circuit interrupter must be used for all portable electrical tools and equipment in confined spaces because most workers will be in contact with grounded surroundings.

Emergency Response Equipment

Fire Extinguishers

"Hot work" inside a confined space requires that an approved fire extinguisher and a person trained in its use be stationed in the confined space or in a suitable vantage point where he or she could effectively suppress any fire that might result from the work.

First Aid Equipment

Blankets, first-aid kit, Stokes stretchers, and any other equipment that may be needed for first-response treatment must be available just outside the confined space. Medical and safety professionals should select equipment on the basis of their evaluations of the potential hazards in the confined space.

Retrieval Equipment

A tripod or another suitable anchorage, hoisting device, harnesses, wristlets, ropes, and any other equipment that may be needed to make a rescue must be identified in the confined-space safe-entry procedures.

It is important that this equipment be available for immediate use. Harnesses and retrieval ropes must be worn by entrants unless they would increase hazards to the entrants or impede their rescue.



Respiratory Protection Section

General

In the Respiratory Protection program, hazard assessment and selection of proper respiratory PPE is conducted in the same manner as for other types of PPE. In the control of those occupational diseases caused by breathing air contaminated with harmful dusts, fogs, fumes, mists, gases, smokes, sprays, or vapors, the primary objective shall be to prevent atmospheric contamination.

This shall be accomplished as far as feasible by accepted engineering control measures (for example, enclosure or confinement of the operation, general and local ventilation, and substitution of less toxic materials). When effective engineering controls are not feasible, or while they are being instituted, appropriate respirators shall be used.

References: OSHA Standards *Respiratory Protection* (29 CFR 1910.134)

Why Respirators Are Needed

Respirators protect against the inhalation of dangerous substances (vapors, fumes, dust, gases). They can also provide a separate air supply in a very hazardous situation.

Some of the health hazards that respirators prevent include

- Lung damage
- Respiratory diseases
- Cancer and other illnesses.

Respiratory Protection Responsibilities

The employer is responsible for:

- Providing training in the use and care of respirators.
- Ensuring that equipment is adequate, sanitary, and reliable.
- Allowing employees to leave area if ill, for breaks, and to obtain parts.
- Fit testing.
- Providing annual medical evaluations.
- Providing a powered air-purifying respirator (PAPR) if an employee cannot wear a tight-fitting respirator.

The employee is responsible for:

- Properly using respirators.
- Maintaining respirator properly.
- Reporting malfunctions.
- Reporting medical changes.

Selection of Respiratory Protection

When choosing the correct respiratory protection for your work environment, it is important to consider:

- Identification of the substance or substances for which respiratory protection is necessary
- A substance's material safety data sheet (MSDS) (it will state which type of respirator is most effective for the substance)
- Activities of the workers
- Hazards of each substance and its properties
- Maximum levels of air contamination expected
- Probability of oxygen deficiency
- Period of time workers will need to use the respiratory protection devices
- Capabilities and physical limitations of the device used



Types of Respirators The following is a description of different types of respirators.

Commonly Used Respirators (Air Purifying)

- **Disposable Dust** masks are worn over the nose and mouth to protect the respiratory system from certain nuisance dusts, mists, etc. They can only provide protection against particular contaminants as specified by the manufacturer (e.g., general dust, fiberglass, etc.). These dust masks cannot be fit tested, and are generally single use. They are not generally recognized as proper respiratory protection and may not be worn if a potential for overexposure exists. They are not included in most companies' Respiratory Protection Programs.
- **Half-Face Respirators** with interchangeable filter cartridges can protect the respiratory system from hazardous dusts, fumes, mists, etc. They can only provide protection against certain contaminants up to limited concentrations specified by the manufacturer for the particular cartridge type used (e.g., toluene, acetone). These generally operate under negative pressure within the respirator which is created by the wearer's breathing through the filter cartridges. As the protection is only gained if there is a proper seal of the respirator face piece, this type requires fit testing prior to respirator assignment and a fit check prior to each use.
- **Full-Face Respirators** operate under the same principle and requirements as the half-face type, however, they offer a better facepiece fit and also protect the wearer's eyes from particularly irritating gases or vapors.
- **Full-face, helmet or hood type powered air purifying respirators (PAPRs)** operate under positive pressure inside the facepiece using a battery operated motor blower assembly to force air through a filter cartridge into the wearer's breathing zone. Use of these respirators is also subject to the manufacturers' guidelines.

Less Commonly Used Types Respirators (Air Supplying)

- **Air-Line Respirators** supply clean air through a small diameter hose from a compressor or compressed air cylinders. The wearer must be attached to the hose at all times, which limits mobility. Use of these respirators is subject to the manufacturers' guidelines.
- **Self-Contained Breathing Apparatus (SCBA)** respirators supply clean air from a compressed air tank carried on the back of the wearer. These types of respirators are highly mobile and are used primarily for emergency response or rescue work, since only a limited amount of air can be supplied by a single tank, generally 20-60 minutes. Units must be thoroughly inspected on a monthly basis and written records must be kept of all inspections, operator training, etc. Use of these respirators is subject to the manufacturer's guidelines

Basic Types of Respirators

Air-purifying or filtering respirators. Such respirators are used when there is enough oxygen (at least 19.5 percent) and contaminants are present below IDLH level. The respirator filters out or chemically "scrubs" contaminants, usually with a replaceable filter. Use color-coded filter cartridges or canisters for different types of contaminants. It's important to select the right filter for the situation.

Air-supplying respirators. These respirators are required when air-purifying respirators aren't effective. Air-purifying respirators are not sufficient in the following settings:

- When there is not enough oxygen.
- Confined spaces.
- When contaminants cannot be filtered out.
- When contaminants are at or above IDLH level.

Different kinds of air-supplying respirators include

- Those connected by hose to stationary air supply (air line)
- Portable tank self-contained breathing apparatus (SCBA).

The Importance of Correct Fit

Even a tiny gap between the respirator and the face can allow contaminants to enter. Respirators should be comfortable and properly fitted. Proper fit includes:

- **Secure but not too tight**
- **No slipping or pinching**
- **Allowance for head movement and speech**

An OSHA-accepted qualitative fit test or quantitative fit test must be performed prior to an employee using any tight-fitting respirator. Tight-fitting respirators must be seal checked before each use by using positive- or negative-pressure check procedures or the manufacturer's instructions.

Respirator Filters/Cartridges

For protection against gases and vapors, the cartridges used for air-purifying respirators must be either equipped with an end-of-service-life indicator (**ESLI**), certified by NIOSH for the contaminant, or a cartridge change schedule has to be established.

For protection against particulates, there are nine classes of filters (three levels of filter efficiency, each with three categories of resistance to filter efficiency degradation). Levels of filter efficiency are 95 percent, 99 percent, and 99.97 percent. Categories of resistance to filter efficiency degradation are labeled N, R, and P.

Protection Factors

The protection factor of a respirator is an expression of performance based on the ratio of two concentrations: The contaminant concentration outside the respirator to the contaminant concentration inside the respirator.

Each class of respirator is also given an assigned protection factor (**APF**). The APF is a measure of the minimum anticipated level of respiratory protection that a properly functioning respirator or class of respirators would provide to a percentage of properly fitted and trained users.

When a contaminant concentration is known, the APF can be used to estimate the concentration inside a particular type of respirator worn by a user.



Who Cannot Wear a Respirator?

Respirator fit is essential. Employees must have a medical checkup to make sure they can wear respirators safely. Generally, respirators cannot be worn when a person:

- **Wears glasses or personal protective equipment that interferes with the seal of the face piece to the face of the user.**
- **Has facial hair that comes between the sealing surface of the face piece and the face or interferes with valve function.**
- **Has a breathing problem, such as asthma.**
- **Has a heart condition.**
- **Is heat sensitive.**

Sometimes a person's facial features will not permit a good fit. Check with the supervisor or medical department if the fit is a problem.

Checking for Damage

Before each use, make sure there are no holes, tears, etc., in the respirator. Rubber parts can wear out and should be checked very carefully every time a respirator is used. Replace worn and damaged parts when necessary. Make sure air and oxygen cylinders are fully charged.

Staying Prepared for Respirator Use

Respirators are bulky and awkward, so getting used to them takes practice. Possible problems with wearing respirators may include heat exhaustion or heat stroke. Be alert for symptoms, use the **"buddy system,"** and wear a lifeline or harness when necessary. Drink plenty of fluids and take frequent breaks.

Poor maneuverability. Practice with respirators in narrow passages, on ladders, etc., if your use of respirators may be in these types of conditions.

Using up the air supply. When a SCBA is in use, keep checking the gauges and listening for alarms; be ready to leave the area immediately if there is a problem.

Panic. Remember the importance of staying calm in a hot, stressful, or awkward situation.

Cleaning Respirators

Respirators should be cleaned and disinfected after every use. Check the respirator for damage before putting it away; look for holes, cracks, deterioration, dented cartridges, etc. If any damage is found, it should be reported to a supervisor. Respirators stored for emergency use must be inspected monthly when not in use, as well as after each use. Respirators should be stored away from light, heat, cold, chemicals, and dust. Store respirators in a **"normal"** (natural, undistorted) position to hold their shape. Do not allow respirators to get crushed, folded, or twisted.

OSHA Overview

OSHA requires that supervisors consult with employees and encourage their participation in the process safety management plan. In fact, managers must have a written plan of action for employee participation in process safety management. Employee participation is critical because...

- **Employees know a lot about the process which they work upon**
- **They play key roles in making sure that process operation is conducted safely.**

Operating Procedures

Managers must furnish written operating procedures that clearly explain how to perform each covered process safely. The procedures must be accurate and must be written in language that people can understand. Avoid technical jargon and, if necessary, supply translations.

Operating procedures must include at least the following:

- Operating steps for initial startup, normal and temporary operations, emergency shutdown (including when it's called for and who does it), emergency operations, normal shutdown, and startup after a turnaround or an emergency shutdown
- Operating limits, including what happens if workers don't conform to operating limits and how to avoid or correct such problems
- Safety and health considerations, such as chemical or other hazards, precautions to prevent exposure, quality and inventory control for chemicals, and what to do if an employee is exposed to a hazardous substance
- Safety systems and their functions, including up-to-date operating procedures and safe work practices.

Contractor Employees

Process safety training and safety programs are also required for contractors who work on-site. Managers must check out the safety performance and programs of any contractors being considered for maintenance, repair, turnaround, major renovation, or specialty work on or around a process covered by the regulation.

When a contractor is hired, the manager must provide the contractor with information on the hazards of the process the contractor will work on. To further ensure contractor safety, managers must also

- ❖ provide the contractor with information on safe work practices for the process they're involved with and tell them what to do in an emergency
- ❖ keep a log of contractor employees' injuries or illnesses related to their work in process areas
- ❖ evaluate the contractor's performance to make sure they're living up to their safety obligations set by the standard.



The Contractor has Responsibilities, too

- Document that employees are trained to recognize hazards and to follow safe work practices on the job
- Make sure that the contractor's employees understand potential job-related hazards, are trained to work safely, and follow the safety rules of the facility in which they're working.

Written Respiratory Protection Program

This paragraph requires the employer to develop and implement a written respiratory protection program with required worksite-specific procedures and elements for required respirator use. The program must be administered by a suitably trained program administrator. In addition, certain program elements may be required for voluntary use to prevent potential hazards associated with the use of the respirator.

The Small Entity Compliance Guide contains criteria for the selection of a program administrator and a sample program that meets the requirements of this paragraph. Copies of the Small Entity Compliance Guide will be available on or about April 8, 1998 from the Occupational Safety and Health Administration's Office of Publications, Room N 3101, 200 Constitution Avenue, NW, Washington, DC, 20210 (202-219-4667).

(c)(1) In any workplace where respirators are necessary to protect the health of the employee or whenever respirators are required by the employer, the employer shall establish and implement a written respiratory protection program with worksite-specific procedures. The program shall be updated as necessary to reflect those changes in workplace conditions that affect respirator use. The employer shall include in the program the following provisions of this section, as applicable:

(c)(1)(i) Procedures for selecting respirators for use in the workplace;

(c)(1)(ii) Medical evaluations of employees required to use respirators;

(c)(1)(iii) Fit testing procedures for tight-fitting respirators;

(c)(1)(iv) Procedures for proper use of respirators in routine and reasonably foreseeable emergency situations;

(c)(1)(v) Procedures and schedules for cleaning, disinfecting, storing, inspecting, repairing, discarding, and otherwise maintaining respirators;

(c)(1)(vi) Procedures to ensure adequate air quality, quantity, and flow of breathing air for atmosphere-supplying respirators;

(c)(1)(vii) Training of employees in the respiratory hazards to which they are potentially exposed during routine and emergency situations;

Example of RP Employee Responsibilities

All Employees shall follow the requirements of the Respiratory Protection Program.

Management

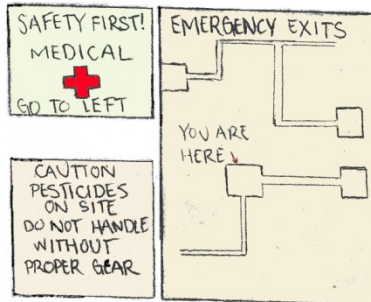
- Implement the requirements of this program.
- Provide a selection of respirators as required.
- Enforce all provisions of this program.
- Appoint a **Specific Designated** individual to conduct the respiratory protection program.

Administrative Department

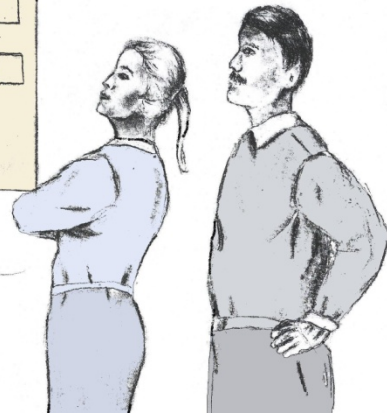
- Review sanitation/storage procedures.
- Ensure respirators are properly stored, inspected and maintained.
- Monitor compliance for this program.
- Provide training for affected Employees.
- Review compliance and ensure monthly inspection of all respirators.
- Provide respirator fit testing.

Designated-Occupational Health Care Provider

- Conducts medical aspects of program.



A handwritten signature in black ink, appearing to be 'J. 108'.



Program Administrator

Each Department will designate a program administrator who is qualified by appropriate training or experience that is commensurate with the complexity of the program to administer or oversee the respiratory protection program and conduct the required evaluations of program effectiveness.

Voluntary Use of Respirators is Prohibited

OSHA requires that voluntary use of respirators, when not required by the Employer, must be controlled as strictly as under required circumstances. To prevent violations of the Respiratory Protection Standard, Employees are not allowed voluntary use of their own or Employer supplied respirators of any type.

Exception: Employees whose only use of respirators involves the voluntary use of filtering (non-sealing) face pieces (dust masks).
See appendix D in the rear.



Respiratory Protection Program Statement *Example*

Facility _____

Policy Statement

A respiratory protection program is hereby established so as to coordinate the use and maintenance or respiratory protective equipment as determined necessary to:

1. Reduce Personnel exposure to toxic chemical agents, harmful dusts, mist and fumes and
2. Allow trained personnel to work safely in hazardous environments, such as welding, oxygen deficient atmospheres, toxic atmospheres, etc.

Designation of Program Administrator

Management has designated _____
to be responsible for the respiratory protection program at this facility. He/she has been delegated authority by Management to make decisions and implement changes in the respirator program anywhere in this facility.

The following responsibilities apply:

1. Supervision of respirator selection process and procedures
2. Establishment of respiratory protection training sessions
3. Establishment of a continuing program of cleaning and inspections
4. Establishment of medical screening program
5. Establishment of issuing procedures
6. Establishment of periodic inspections
7. Continuing evaluation of all aspects of the respiratory protection program to assure continued effectiveness
8. Establishment of annual fit tests procedures

Any questions or problems concerning respirators or their use should be directed to the Program Administrator

Facility Manager

Date



Program Evaluation

Evaluations of the workplace are necessary to ensure that the written respiratory protection program is being properly implemented; this includes consulting with employees to ensure that they are using the respirators properly. Evaluations shall be conducted as necessary to ensure that the provisions of the current written program are being effectively implemented and that it continues to be effective.

Program evaluation will include discussions with employees required to use respirators to assess the employees' views on program effectiveness and to identify any problems.

Any problems that are identified during this assessment shall be corrected. Factors to be assessed include, but are not limited to:

- Respirator fit (including the ability to use the respirator without interfering with effective workplace performance);
- Appropriate respirator selection for the hazards to which the employee is exposed;
- Proper respirator use under the workplace conditions the employee encounters; and
- Proper respirator maintenance.



RP Recordkeeping

The employer will retain written information regarding medical evaluations, fit testing, and the respiratory protection program.

This information will facilitate employee involvement in the respiratory protection program, assist the Employer in auditing the adequacy of the program, and provide a record for compliance determinations by OSHA.

Training and Information

Effective training for employees who are required to use respirators is essential. The training must be comprehensive, understandable, and recur annually and more often if necessary. Training will be provided prior to requiring the employee to use a respirator in the workplace.

The training shall ensure that each employee can demonstrate knowledge of at least the following:

- Why the respirator is necessary and how improper fit, usage, or maintenance can compromise the protective effect of the respirator
- Limitations and capabilities of the respirator
- How to use the respirator effectively in emergency situations, including situations in which the respirator malfunctions
- How to inspect, put on and remove, use, and check the seals of the respirator
- Procedures for maintenance and storage of the respirator
- How to recognize medical signs and symptoms that may limit or prevent the effective use of respirators
- The general requirements of this program

Retraining shall be conducted annually and when:

- changes in the workplace or the type of respirator render previous training obsolete
- inadequacies in the employee's knowledge or use of the respirator indicate that the employee has not retained the requisite understanding or skill
- other situation arises in which retraining appears necessary to ensure safe respirator use

Training is divided into the following sections:

Classroom Instruction

1. Overview of the Employer's Respiratory Protection Program & OSHA Standard.
2. Respiratory Protection Safety Procedures.
3. Respirator Selection.
4. Respirator Operation and Use.
5. Why the respirator is necessary.
6. How improper fit, usage, or maintenance can compromise the protective effect.
7. Limitations and capabilities of the respirator.
8. How to use the respirator effectively in emergency situations, including respirator malfunctions.
9. How to inspect, put on and remove, use, and check the seals of the respirator.
10. Procedures for maintenance and storage of the respirator.
11. How to recognize medical signs and symptoms that may limit or prevent the effective use of respirators.
12. Change out schedule and procedure for air purifying respirators.

Respiratory Protection Program

Training Certificate *Example*

Name: _____

Department: _____ Date: _____

I have received Training on the Respiratory Protection Program. The Training included the following:

Classroom Training

- ✓ Overview of the Company Respiratory Protection Program
- ✓ Respiratory Protection Safety Procedures
- ✓ Respirator Selection
- ✓ Respirator Operation and Use
- ✓ Why the respirator is necessary
- ✓ How improper fit, usage, or maintenance can compromise the protective effect.
- ✓ Limitations and capabilities of the respirator.
- ✓ How to use the respirator effectively in emergency situations, including respirator malfunctions
- ✓ How to inspect, put on and remove, use, and check the seals of the respirator.
- ✓ Procedures for maintenance and storage of the respirator.
- ✓ How to recognize medical signs and symptoms that may limit or prevent the effective use of respirators.
- ✓ Respirator filter & cartridge change out schedule
- ✓ The general requirements of this program

Hands-on Training

- ✓ Respirator Inspection
- ✓ Respirator cleaning and sanitizing
- ✓ Fit Check
- ✓ Record Keeping
- ✓ Respirator Storage
- ✓ Emergencies

Employee Signature

Trainer's Signature

Fit Testing Hands-On Respirator Training

(see appendix A for more information)

1. Respirator Inspection
2. Respirator cleaning and sanitizing
3. Record Keeping
4. Respirator Storage
5. Respirator Fit Check
6. Emergencies



Basic Respiratory Protection Safety Procedures

1. Only authorized and trained employees may use respirators. Those employees may use only the respirator that they have been trained on and properly fitted to use.
2. Only physically qualified employees may be trained and authorized to use respirators. A pre-authorization and annual certification by a qualified physician will be required and maintained. Any changes in an Employee's health or physical characteristics will be reported to the Occupational Health Department and will be evaluated by a qualified physician.
3. Only the proper prescribed respirator or SCBA may be used for the job or work environment. Air cleansing respirators may be worn in work environments when oxygen levels are between 19.5 percent to 23.5 percent and when the appropriate air cleansing canister, as determined by the Manufacturer and approved by NIOSH or MESA, for the known hazardous substance is used. SCBAs will be worn in oxygen deficient and oxygen rich environments (below 19.5 percent or above 23.5 percent oxygen).
4. Employees working in environments where a sudden release of a hazardous substance is likely will wear an appropriate respirator for that hazardous substance (example: employees working in an ammonia compressor room will have an ammonia APR respirator on their person.).
5. Only SCBAs will be used in oxygen deficient environments, environments with an unknown hazardous substance or unknown quantity of a known hazardous substance or any environment that is determined "**Immediately Dangerous to Life or Health**" (IDLH).
6. Employees with respirators loaned on "permanent check out" will be responsible for the sanitation, proper storage and security. Respirators damaged by normal wear will be repaired or replaced by the employer when returned.
7. The last employee using a respirator and/or SCBA that are available for general use will be responsible for proper storage and sanitation. Monthly and after each use, all respirators will be inspected with documentation to assure its availability for use.
8. All respirators will be located in a clean, convenient and sanitary location.
9. In the event that employees must enter a confined space, work in environments with hazardous substances that would be dangerous to life or health should an RPE fail (a SCBA is required in this environment), and/or conduct a HAZMAT entry, a "**buddy system**" detail will be used with a safety watchman with constant voice, visual or signal line communication. Employees will follow the established emergency response program and/or confined space entry program when applicable.
10. Management will establish and maintain surveillance of jobs and work place conditions and degree of employee exposure or stress to maintain the proper procedures and to provide the necessary RPE.
11. Management will establish and maintain safe operation procedures for the safe use of RPE with strict enforcement and disciplinary action for failure to follow all general and specific safety rules. Standard operation procedures for general RPE use will be maintained as an attachment to the respiratory protection program and standard operation procedures for RPE use under emergency response situations will be maintained as an attachment to the emergency response program.

Selection of Respirators

The employer is responsible for and needs to have evaluated the respiratory hazard(s) in each workplace, identified relevant workplace and user factors and have based respirator selection on these factors. Also included are estimates of employee exposures to respiratory hazard(s) and an identification of the contaminant's chemical state and physical form.

This selection has included appropriate protective respirators for use in IDLH atmospheres, and has limited the selection and use of air-purifying respirators. All selected respirators are NIOSH-certified.

Filter Classifications - These classifications are marked on the filter or filter package

N-Series: Not Oil Resistant

- Approved for non-oil particulate contaminants
- Examples: dust, fumes, mists not containing oil

R-Series: Oil Resistant

- Approved for all particulate contaminants, including those containing oil
- Examples: dusts, mists, fumes
- Time restriction of 8 hours when oils are present

P-Series: Oil Proof

- Approved for all particulate contaminants including those containing oil
- Examples: dust, fumes, mists
- See Manufacturer's time use restrictions on packaging



Respirators for IDLH Atmospheres

- The following respirators will be used in IDLH atmospheres:
- A full face piece pressure demand SCBA certified by NIOSH for a minimum service life of thirty minutes, or
- A combination full face piece pressure demand supplied-air respirator (**SAR**) with auxiliary self-contained air supply.
- Respirators provided only for escape from IDLH atmospheres shall be NIOSH-certified for escape from the atmosphere in which they will be used.

Respirators for Atmospheres that are not for IDLH

The respirators selected shall be adequate to protect the health of the employee and ensure compliance with all other OSHA statutory and regulatory requirements, under routine and reasonably foreseeable emergency situations. The respirator selected shall be appropriate for the chemical state and physical form of the contaminant.

Identification of Filters & Cartridges

All filters and cartridges shall be labeled and color coded with the NIOSH approval label; the label is not to be removed and must remain legible. A change out schedule for filters and canisters has been developed to ensure the elements of the respirators remain effective.

Respirator Filter & Canister Replacement

An important part of the Respiratory Protection Program includes identifying the useful life of canisters and filters used on air-purifying respirators. Each filter and canister shall be equipped with an end-of-service-life indicator (**ESLI**) certified by NIOSH for the contaminant; or If there is no ESLI appropriate for conditions a change schedule for canisters and cartridges that is based on objective information or data that will ensure that canisters and cartridges are changed before the end of their service life.



It is unacceptable maintenance and storage (OSHA Violation).

Filter & Cartridge Change Schedule

Stock of spare filters and cartridges shall be maintained to allow immediate change when required or desired by the employee.

Cartridges shall be changed based on the most limiting factor below:

- Prior to expiration date
- Manufacturer's recommendations for the specific use and environment
- After each use
- When requested by employee
- When contaminate odor is detected
- When restriction to air flow has occurred as evidenced by increased effort by user to breathe normally
- Cartridges shall remain in their original sealed packages until needed for immediate use

Filters shall be changed on the most limiting factor below:

- Prior to expiration date
- Manufacturer's recommendations for the specific use and environment
- When requested by employee
- When contaminate odor is detected
- When restriction to air flow has occurred as evidenced by increased effort by user to breathe normally
- When discoloring of the filter media is evident
- Filters shall remain in their original sealed package until needed for immediate use.

RESPIRATORY PROTECTION PROGRAM CHECKLIST		PAGE 1 OF 1 PAGES			
DIVISION:		SECTION:	SUPERVISOR:	DATE:	
			YES	NO	NA
1	Is respiratory protection (RP) being worn in the section?				
2	Has air sampling been accomplished that mandates using RP?				
3	Where air sampling results greater than Occupational Exposure Limits? (If NO, why are you using a respirator?)				
4	Has a Hazard Assessment been generated concerning the task or process that placed the section on the RP Program?				
5	Have all processes that may warrant the use of RP been evaluated? (If NO, request an assessment from the Department Safety Analyst /Personnel Safety, unless the operation is emergency response).				
6	Have workers received physicals and been found medically qualified to wear RP?				
7	Is there documentation that workers were formally briefed on air sampling results and why RP is required?				
8	Is respiratory protection training and fit-testing documentation available on everyone who wears a respirator?				
9	Are RP wearers being fit-tested at least annually?				
10	Are section employees wearing RP voluntarily when conditions have not mandated their use?				
11	Are employees wearing contacts in hazardous atmospheres or using eye-wear that negates face to face piece seal?				
12	Do RP users have facial hair that negates face to face piece seal?				
13	Has a respirator inventory been compiled that list the type of respirator(s) used in the workplace? (Use Respirator Inventory Worksheet attach to this checklist)				
14	Has the Section Supervisor received formal RP training on OSHA, City Personnel Safety and Respiratory Protection Program requirements and his or her responsibilities?				
15	Does the section have written standard operating instructions governing the selection, fit-testing, use, cleaning, storage and maintenance of respirators?				
16	Is the Fire Department the only source being used to charge SCBA's with compressed air?				
17	Are SCBA's being inspected at least every 30 days?				
18	Does the section have on hand, applicable OSHA, CITY, and Section Respiratory Protection Program guidance documents?				
19	Are periodic audits of the section's RP program conducted with discrepancies tracked until closed out?				
20	Have program deficiencies been elevated to the Director and Department Safety Analyst?				
SURVEYED BY:		REVIEWED BY:			

Respiratory Protection Schedule by Job and Working Condition

The employer needs to maintain a Respiratory Protection Schedule by Job and working condition. This schedule is provided to each authorized and trained employee.

The Schedule provides the following information:

1. Job/Working conditions.
2. Work location.
3. Hazards present.
4. Type of respirator or SCBA required.
5. Type of filter/canister required.
6. Location of respirator or SCBA.
7. Filter/Cartridge change out schedule.

The schedule will be reviewed and updated at least annually and whenever any changes are made in the work environments, machinery, equipment, or processes or if respirator different respirator models are introduced or existing models are removed.



Permanent respirator Schedule Assignments are:

Each person who engages in welding will have their own employer provided dust-mist-fume filter APR. This respirator will be worn during all welding operations.

Physical and Medical Qualifications

Records of medical evaluations must be retained and made available in accordance with 29 CFR 1910.1020.

Medical Evaluation Required

Using a respirator may place a physiological burden on employees that varies with the type of respirator worn, the job and workplace conditions in which the respirator is used, and the medical status of the employee. The Employer is required to provide a medical evaluation to determine the employee's ability to use a respirator before the employee is fit tested or required to use the respirator in the workplace.

Medical Evaluation Procedures

The employee will be provided a medical questionnaire by the designated Occupational Health Care Provider.



Follow-up Medical Examination

The employer shall ensure that a follow-up medical examination is provided for an employee who gives a positive response to any question among questions in Part B of the questionnaire or whose initial medical examination demonstrates the need for a follow-up medical examination. The follow-up medical examination shall include any medical tests, consultations, or diagnostic procedures that the physician deems necessary to make a final determination.

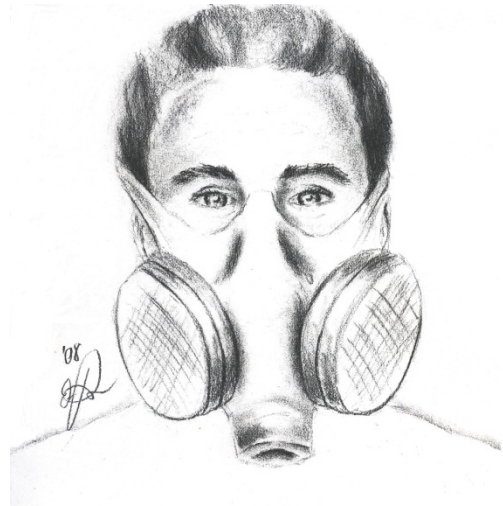
Administration of the Medical Questionnaire and Examinations.

The medical questionnaire and examinations shall be administered confidentially during the employee's normal working hours or at a time and place convenient to the employee. The medical questionnaire shall be administered in a manner that ensures that the employee understands its content. The employer shall provide the employee with an opportunity to discuss the questionnaire and examination results with the Physician.

Supplemental Information for the Physician

The following information must be provided to the physician before the Physician makes a recommendation concerning an employee's ability to use a respirator.

- The type and weight of the respirator to be used by the employee
- The duration and frequency of respirator use (including use for rescue and escape)
- The expected physical work effort
- Additional protective clothing and equipment to be worn
- Temperature and humidity extremes that may be encountered
- Any supplemental information provided previously to the physician regarding an employee need not be provided for a subsequent medical evaluation if the information and the physician remain the same.



The employer has provided the physician with a copy of the written respiratory protection program and a copy of the OSHA Standard 1910.134

Acronyms

Qualitative fit test (QLFT) means a pass/fail fit test to assess the adequacy of respirator fit that relies on the individual's response to the test agent.

Quantitative fit test (QNFT) means an assessment of the adequacy of respirator fit by numerically measuring the amount of leakage into the respirator.

Medical Determination

In determining the employee's ability to use a respirator, the employer shall:

- Obtain a written recommendation regarding the employee's ability to use the respirator from the physician. The recommendation shall provide only the following information:
 - Any limitations on respirator use related to the medical condition of the employee, or relating to the workplace conditions in which the respirator will be used, including whether or not the employee is medically able to use the respirator.
 - The need, if any, for follow-up medical evaluations.
 - A statement that the Physician has provided the employee with a copy of the physician's written recommendation.

- If the respirator is a negative pressure respirator and the physician finds a medical condition that may place the employee's health at increased risk if the respirator is used, the employer shall provide an APR if the physician's medical evaluation finds that the employee can use such a respirator; if a subsequent medical evaluation finds that the employee is medically able to use a negative pressure respirator, then the employer is no longer required to provide an APR.

Additional Medical Evaluations

At a minimum, the employer shall provide additional medical evaluations that comply with the requirements of this section if:

- An employee reports medical signs or symptoms that are related to the ability to use a respirator
- A physician, supervisor, or the respirator program administrator informs the employer that an employee needs to be reevaluated
- Information from the respiratory protection program, including observations made during fit testing and program evaluation, indicates a need for employee reevaluation
- A change occurs in workplace conditions (e.g., physical work effort, protective clothing, and temperature) that may result in a substantial increase in the physiological burden placed on an employee.

Respirator Fit Testing (see Appendix A for more information)

Before an employee is required to use any respirator with a negative or positive pressure tight-fitting face piece, the employee must be fit tested with the same make, model, style, and size of respirator that will be used. The Employer shall ensure that an employee using a tight-fitting face piece respirator is fit tested prior to initial use of the respirator, whenever a different respirator face piece (size, style, model or make) is used, and at least annually thereafter.

The employer has established a record of the qualitative and quantitative fit tests administered to employees including:

- The name or identification of the employee tested
- Type of fit test performed
- Specific make, model, style, and size of respirator tested
- Date of test
- The pass/fail results for QLFTs or the fit factor and strip chart recording or other recording of the test results for QNFTs

Additional fit tests will be conducted whenever the employee reports, or the employer, physician, supervisor, or program administrator makes visual observations of, changes in the employee's physical condition that could affect respirator fit.

Such conditions include, but are not limited to, facial scarring, dental changes, cosmetic surgery, or an obvious change in body weight.

If after passing a QLFT or QNFT, the employee notifies the employer's program administrator, supervisor, or physician that the fit of the respirator is unacceptable, the employee shall be given a reasonable opportunity to select a different respirator face piece and to be retested.

Types of Fit Tests

The fit test shall be administered using an OSHA-accepted QLFT or QNFT protocol. The OSHA-accepted QLFT and QNFT protocols and procedures are contained in Appendix A of OSHA Standard 1910.134.

- QLFT may only be used to fit test negative pressure air-purifying respirators that must achieve a fit factor of 100 or less.
- If the fit factor, as determined through an OSHA-accepted QNFT protocol, is equal to or greater than 100 for tight-fitting half face pieces, or equal to or greater than 500 for tight-fitting full face pieces, the QNFT has been passed with that respirator.

- Fit testing of tight-fitting atmosphere-supplying respirators and tight-fitting powered air-purifying respirators shall be accomplished by performing quantitative or qualitative fit testing in the negative pressure mode, regardless of the mode of operation (negative or positive pressure) that is used for respiratory protection.
- Qualitative fit testing of these respirators shall be accomplished by temporarily converting the respirator user's actual face piece into a negative pressure respirator with appropriate filters, or by using an identical negative pressure air-purifying respirator face piece with the same sealing surfaces as a surrogate for the atmosphere-supplying or powered air-purifying respirator face piece.
- Quantitative fit testing of these respirators shall be accomplished by modifying the face piece to allow sampling inside the face piece in the breathing zone of the user, midway between the nose and mouth. This requirement shall be accomplished by installing a permanent sampling probe onto a surrogate face piece, or by using a sampling adapter designed to temporarily provide a means of sampling air from inside the face piece.
- Any modifications to the respirator face piece for fit testing shall be completely removed, and the face piece restored to NIOSH approved configuration, before that face piece can be used in the workplace.

Fit test records shall be retained for respirator users until the next fit test is administered. Written materials required to be retained shall be made available upon request to affected employees.

Respirator Operation and Use

Respirators will only be used following the respiratory protection safety procedures established in this program. The Operations and Use Manuals for each type of respirator will be maintained by the program administrator and be available to all qualified users.

Surveillance by the direct supervisor shall be maintained of work area conditions and degree of employee exposure or stress. When there is a change in work area conditions or degree of employee exposure or stress that may affect respirator effectiveness, the employer shall reevaluate the continued effectiveness of the respirator.

For continued protection of respirator users, the following general use rules apply:

- Users shall not remove respirators while in a hazardous environment
- Respirators are to be stored in sealed containers out of harmful atmospheres
- Store respirators away from heat and moisture
- Store respirators such that the sealing area does not become distorted or warped
- Store respirators such that the face piece is protected
- Face piece seal protection

The Employer does not permit respirators with tight-fitting face pieces to be worn by employees who have:

- Facial hair that comes between the sealing surface of the face piece and the face or that interferes with valve function; or
- Any condition that interferes with the face-to-face piece seal or valve function.

If an employee wears corrective glasses or goggles or other personal protective equipment, the employer shall ensure that such equipment is worn in a manner that does not interfere with the seal of the face piece to the face of the user.

Continuing Effectiveness of Respirators

The employer shall ensure that employees leave the respirator use area for the following:

- To wash their faces and respirator face pieces as necessary to prevent eye or skin irritation associated with respirator use
- If they detect vapor or gas breakthrough, changes in breathing resistance, or leakage of the face piece

- To replace the respirator or the filter, cartridge, or canister elements.

If the employee detects vapor or gas breakthrough, changes in breathing resistance, or leakage of the face piece, the employer will replace or repair the respirator before allowing the employee to return to the work area.

Procedures for IDLH atmospheres

For all IDLH atmospheres, the Employer shall ensure that:

- One employee or, when needed, more than one employee is located outside the IDLH atmosphere
- Visual, voice, or signal line communication is maintained between the employee(s) in the IDLH atmosphere and the employee(s) located outside the IDLH atmosphere
- The employee(s) located outside the IDLH atmosphere are trained and equipped to provide effective emergency rescue
- The employer or designee is notified before the employee(s) located outside the IDLH atmosphere enter the IDLH atmosphere to provide emergency rescue
- The employer or designee authorized to do so by the employer, once notified, provides necessary assistance appropriate to the situation

Employee(s) located outside the IDLH atmospheres will be equipped with:

- Pressure demand or other positive pressure SCBAs, or a pressure demand or other positive pressure supplied-air respirator with auxiliary SCBA; and either
- Appropriate retrieval equipment for removing the employee(s) who enter(s) these hazardous atmospheres where retrieval equipment would contribute to the rescue of the employee(s) and would not increase the overall risk resulting from entry; or
- Equivalent means for rescue where retrieval equipment is not required.



OSHA's General Industry Regulation, §1910.146 Permit-required confined spaces, contains requirements for practices and procedures to protect employees in general industry from the hazards of entry into permit-required confined spaces. This regulation does not apply to construction.

OSHA's Construction Safety and Health Regulations Part 1926 do not contain a permit-required confined space regulation. Subpart C, §1926.21 Safety training and education specifies training for personnel who are required to enter confined spaces and defines a "**confined or enclosed space**."

Gas and Vapor Contaminants

Gas and vapor contaminants can be classified according to their chemical characteristics. True gaseous contaminants are similar to air in that they possess the same ability to diffuse freely within an area or container. Nitrogen, chlorine, carbon monoxide, carbon dioxide and sulfur dioxide are examples.

Vapors are the gaseous state of substances that are liquids or solids at room temperature. They are formed when the solid or liquid evaporates. Gasoline, solvents and paint thinners are examples of liquids that evaporate easily, producing vapors.

In terms of chemical characteristics, gaseous contaminants may be classified as follows:

- **Inert Gases** —These include such true gases as helium, argon, neon, etc. Although they do not metabolize in the body, these gases represent a hazard because they can produce an oxygen deficiency by displacement of air.
- **Acidic Gases** —Often highly toxic, acidic gases exist as acids or produce acids by reaction with water. Sulfur dioxide, hydrogen sulfide and hydrogen chloride are examples.
- **Alkaline Gases** —These gases exist as alkalis or produce alkalis by reaction with water. Ammonia and phosphine are two examples.

In terms of chemical characteristics, vaporous contaminants may be classified as follows:

- **Organic Compounds** —Contaminants in this category can exist as true gases or vapors produced from organic liquids. Gasoline, solvents and paint thinners are examples.
- **Organometallic Compounds** —These are generally comprised of metals attached to organic groups. Tetraethyllead and organic phosphates are examples.

Hazard Assessment

Proper assessment of the hazard is the first important step to protection. This requires a thorough knowledge of processes, equipment, raw materials, end-products and by-products that can create an exposure hazard.

To determine an atmosphere's oxygen content or concentration levels of particulate and/or gaseous contaminants, air samples must be taken with proper sampling instruments during all conditions of operation. The sampling device and the type and frequency of sampling (spot testing or continuous monitoring) will be dictated by the exposure and operating conditions.

Breathing zone samples are recommended and sampling frequency should be sufficient to assess the average exposure under the variable operating and exposure conditions. Should contaminant concentrations exceed exposure limits recommended by the American Conference of Governmental Industrial Hygienists (**ACGIH**), OSHA or NIOSH, hazard control procedures must be implemented promptly. Exposure monitoring plays a critical role in the respirator selection process. The results from such tests will help you determine whether respiratory protection is needed and, if it is, the type of respirator required. Generally, respirator selection is based on three factors:

- The results of your atmospheric monitoring or sampling program;
- The accepted ACGIH, OSHA or NIOSH exposure limits for the substance(s) present;
- And the maximum use concentration (of a substance) for which a respirator can be used.

Exposure limits include ACGIH Threshold Limit Values (**TLVs**), OSHA Permissible Exposure Limits (**PELs**), NIOSH Recommended Exposure Levels (**RELs**) and AIHA Workplace Environmental Exposure Levels (**WEELs**). These values are guides for exposure concentrations that healthy individuals can normally tolerate for eight hours a day, five days a week without harmful effects. Unless otherwise noted, exposure limits are eight-hour, time-weighted-average (**TWA**) concentrations.

In general, gas and vapor exposure limits are expressed in ppm by volume (parts of contaminant per million parts of air), while particulate concentrations are expressed as mg/m³ (milligrams of concentrations per cubic meter of air). For substances that can exist in more than one form (particulate or gaseous), concentrations are expressed in both values.

It is important to note that exposure limits and other exposure standards are constantly changing as more data is gathered about specific chemicals and substances. As such, you must be certain that you are using the most recent data when determining allowable exposure levels for employees.

Hazard Control

Hazard control should start at the process, equipment and plant design levels where contaminants can be effectively controlled at the outset. With operating processes, the problem becomes more difficult. In all cases, however, consideration should be given to the use of effective engineering controls to eliminate and/or reduce exposures to respiratory hazards. This includes consideration of process encapsulation or isolation, use of less toxic materials in the process and suitable exhaust ventilation, filters and scrubbers to control the effluents. Because it is sometimes not practical to maintain engineering controls that eliminate all airborne concentrations of contaminants, proper respiratory protective devices should be used whenever such protection is required.

Hazard Assessment or Hazard Certification sheet example is on the following page.

Even if you have a written RP Program and complete training records, OSHA will ask for a hazard certification or assessment form on where or why you need RP. For example, if you were required to don SCBA to change a chlorine cylinder once a week, OSHA would request to see how that task was evaluated and certified.

RP Cleaning and Disinfecting *(See Appendix B for more information)*

The employer shall provide each respirator user with a respirator that is clean, sanitary, and in good working order. The employer shall ensure that respirators are cleaned and disinfected using the Standard Operating Procedure SOP: Cleaning and Disinfecting.

The respirators shall be cleaned and disinfected when:

- Respirators issued for the exclusive use of an employee shall be cleaned and disinfected as often as necessary to be maintained in a sanitary condition.
- Respirators issued to more than one employee shall be cleaned and disinfected before being worn by different individuals.
- Respirators maintained for emergency use shall be cleaned and disinfected after each use.
- Respirators used in fit testing and training shall be cleaned and disinfected after each use.

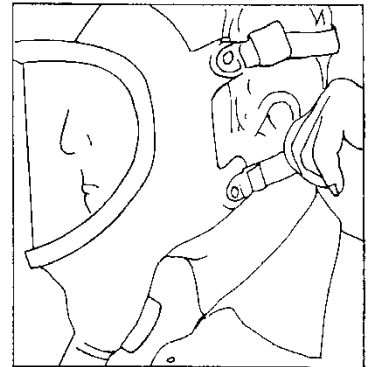
Cleaning and Storage of respirators assigned to specific employees is the responsibility of that employee.

Respirator Inspection

All respirators/SCBAs, both available for "**General Use**" and those on "**Permanent Check-out**", will be inspected after each use and at least monthly. Should any defects be noted, the respirator/SCBA will be taken to the program Administrator. Damaged Respirators will be either repaired or replaced. The inspection of respirators loaned on "**Permanent Check-out**" is the responsibility of that trained employee.

Respirators shall be inspected as follows:

- All respirators used in routine situations shall be inspected before each use and during cleaning.
- All respirators maintained for use in emergency situations shall be inspected at least monthly and in accordance with the manufacturer's recommendations, and shall be checked for proper function before and after each use.
- Emergency escape-only respirators shall be inspected before being carried into the workplace for use.

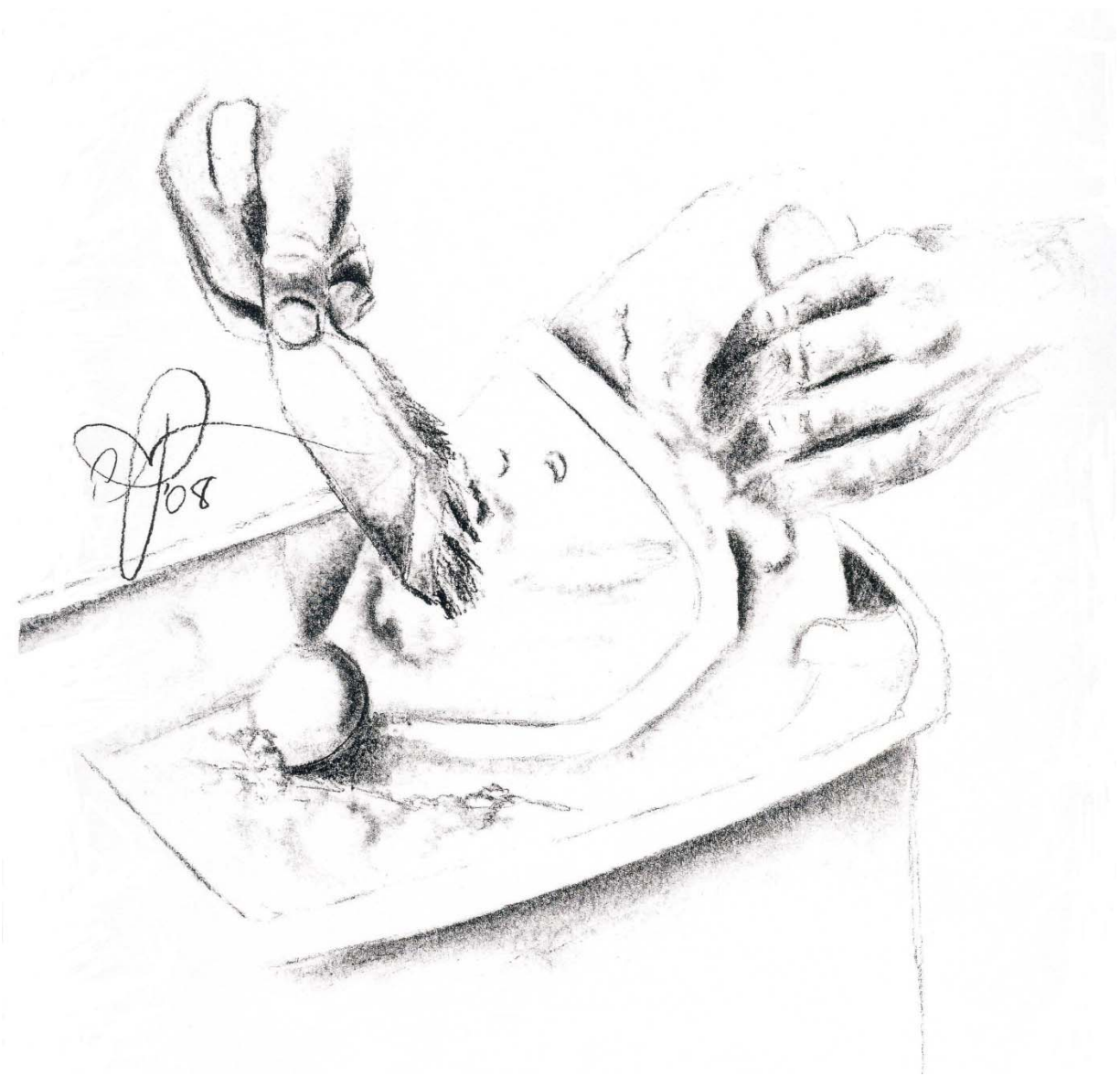


Respirator inspections include the following:

- A check of respirator function, tightness of connections, and the condition of the various parts including, but not limited to, the face piece, head straps, valves, connecting tube, and cartridges, canisters or filters
- Check of elastomeric parts for pliability and signs of deterioration.
- Self-contained breathing apparatus shall be inspected monthly. Air and oxygen cylinders shall be maintained in a fully charged state and shall be recharged when the pressure falls to 90% of the manufacturer's recommended pressure level. The employer shall determine that the regulator and warning devices function properly

For Emergency Use Respirators the additional requirements apply:

- Certify the respirator by documenting the date the inspection was performed, the name (or signature) of the person who made the inspection, the findings, required remedial action, and a serial number or other means of identifying the inspected respirator.
- Provide this information on a tag or label that is attached to the storage compartment for the respirator, is kept with the respirator, or is included in inspection reports stored as paper or electronic files. This information shall be maintained until replaced following a subsequent certification.



Respirator Storage

Respirators are to be stored as follows:

- All respirators shall be stored to protect them from damage, contamination, dust, sunlight, extreme temperatures, excessive moisture, and damaging chemicals, and they shall be packed or stored to prevent deformation of the face piece and exhalation valve.
- **Emergency Respirators shall be:**
 - Kept accessible to the work area;
 - Stored in compartments or in covers that are clearly marked as containing emergency respirators; and
 - Stored in accordance with any applicable manufacturer instructions.

Repair of Respirators

Respirators that fail an inspection or are otherwise found to be defective will be removed from service to be discarded, repaired or adjusted in accordance with the following procedures:

- Repairs or adjustments to respirators are to be made only by persons appropriately trained to perform such operations and shall use only the respirator manufacturer's NIOSH-approved parts designed for the respirator;
- Repairs shall be made according to the manufacturer's recommendations and specifications for the type and extent of repairs to be performed; and
- Reducing and admission valves, regulators, and alarms shall be adjusted or repaired only by the manufacturer or a technician trained by the manufacturer.

Breathing Air Quality and Use

The employer shall ensure that compressed air, compressed oxygen, liquid air, and liquid oxygen used for respiration accords with the following specifications:

- Compressed and liquid oxygen shall meet the United States Pharmacopoeia Requirements for medical or breathing oxygen; and
- Compressed breathing air shall meet at least the requirements for Grade D breathing air described in ANSI/Compressed Gas Association Commodity Specification for Air, G-7.1-1989, to include:
 - Oxygen content (v/v) of 19.5-23.5%;
 - Hydrocarbon (condensed) content of 5 milligrams per cubic meter of air or less;
 - Carbon monoxide content of 10 ppm or less;
 - Carbon dioxide content of 1,000 ppm or less; and
 - Lack of noticeable odor.
- Compressed oxygen will not be used in atmosphere-supplying respirators that have previously used compressed air.
- Oxygen concentrations greater than 23.5% are used only in equipment designed for oxygen service or distribution.

Cylinders used to supply breathing air to respirators meet the following requirements:

- Cylinders are tested and maintained as prescribed in the Shipping Container Specification Regulations of the Department of Transportation (49 CFR part 173 and part 178).
- Cylinders of purchased breathing air have a certificate of analysis from the supplier that the breathing air meets the requirements for Grade D breathing air.
- Moisture content in breathing air cylinders does not exceed a dew point of -50 deg. F (-45.6 deg. C) at 1 atmosphere pressure.
- Breathing air couplings are incompatible with outlets for non-respirable worksite air or other gas systems. No asphyxiating substance shall be introduced into breathing air lines.
- Breathing gas containers shall be marked in accordance with the NIOSH respirator certification standard, 42 CFR part 84.

Summary



Following this training session, employees should:

- Wear the respirator assigned to him or her
- Always check for fit before wearing
- Always check for damage and deterioration before wearing
- Know when to replace canisters and cartridges
- Practice maneuvering with a respirator
- Store carefully in the proper location.

Glossary

ABIOGENESIS: The concept of spontaneous generation (that life can come from non-life). This idea was refuted by Pasteur.

ABIOTIC: The non-living components of an organism's environment. The term abiotic is also used to denote a process which is not facilitated by living organisms.

ABORAL: Pertaining to the region of the body opposite that of the mouth. Normally used to describe radially symmetrical animals.

ABSCISIC ACID (ABA): A plant hormone that generally acts to inhibit growth, promote dormancy, and help the plant withstand stressful conditions.

ABSENCE OF OXYGEN: The complete absence of oxygen in water described as Anaerobic.

ABSORPTION SPECTRUM: The range of a material's ability to absorb various wavelengths of light. The absorption spectrum is studied to evaluate the function of photosynthetic pigments.

ACCURACY: How closely an instrument measures the true or actual value.

ACCESSORY PIGMENT: A photosynthetic pigment which absorbs light and transfers energy to chlorophylls during photosynthesis. Because accessory pigments have different absorption optima than chlorophylls, presence of accessory pigments allows photosynthetic systems to absorb light more efficiently than would be possible otherwise.

ACELLULAR: Not within cells. Sometimes used as a synonym for unicellular (but multinucleate). Unicellular also pertains to single: celled organisms.

ACETYL COA: Acetyl CoenzymeA is the entry compound for the Krebs cycle in cellular respiration; formed from a fragment of pyruvic acid attached to a coenzyme.

ACETYLCHOLINE: A neurotransmitter substance that carries information across vertebrate neuromuscular junctions and some other synapses.

ACID: Slowly add the acid to water while stirring. An operator should not mix acid and water or acid to a strong base.

ACID AND BASE ARE MIXED: When an acid and a base are mixed, an explosive reaction occurs and decomposition products are created under certain conditions.

ACID RAIN: Rain that is excessively acidic due to the presence of acid: causing pollutants in the atmosphere. Pollutants include nitrogen and sulfur oxides due to burning of coal and oil.

ACIDOSIS: A condition whereby the hydrogen ion concentration of the tissues is increased (and pH decreased). Respiratory acidosis is due to the retention of CO₂; metabolic acidosis by retention of acids due either to kidney failure or diarrhea.

ACOELOMATE: Lacking a coelom.

ACQUIRED IMMUNITY: Results from exposure to foreign substances or microbes (also called natural immunity).

ACROSOME: An organelle at the tip of a sperm cell that helps the sperm penetrate the egg.

ACTH (adrenocorticotrophic hormone): A proteinaceous hormone from the anterior pituitary that stimulates the adrenal cortex. Used to stimulate the production of cortisol.

ACTIN: A globular protein that links into chains, two of which twist helically about each other, forming microfilaments in muscle and other contractile elements in cells.

ACTION POTENTIAL: The stimulus- triggered change in the membrane potential of an excitable cell, caused by selective opening and closing of ion channels.

ACTION SPECTRUM: A graph which illustrates the relationship between some biological activity and wavelength of light.

ACTIVATING ENZYME: An enzyme that couples a low-energy compound with ATP to yield a high-energy derivative.

ACTIVATION ENERGY: In a chemical reaction, the initial investment required to energize the bonds of the reactants to an unstable transition state that precedes the formation of the products.

ACTIVE SITE: That specific portion of an enzyme that attaches to the substrate by means of weak chemical bonds.

ACTIVE TRANSPORT: The movement of a substance across a biological membrane against its concentration or electrochemical gradient with the help of energy input and specific transport proteins.

ACTIVATED SLUDGE: The biologically active solids in an activated sludge process wastewater treatment plant.

ACTIVATED SLUDGE PROCESS: A biological wastewater treatment process in which a mixture of wastewater and biologically enriched sludge is mixed and aerated to facilitate aerobic decomposition by microbes.

ADAPTATION: Any genetically controlled characteristic that increases an organism's fitness, usually by helping the organism to survive and reproduce in the environment it inhabits.

ADAPTIVE RADIATION: This refers to the rapid evolution of one or a few forms into many different species that occupy different habitats within a new geographical area.

ADHESION: In chemistry, the phenomenon whereby one substance tends to cling to another substance. Water molecules exhibit adhesion, especially toward charged surfaces.

ADP (Adenosine diphosphate): A doubly phosphorylated organic compound that can be further phosphorylated to form ATP.

ADRENAL GLAND: An endocrine gland located adjacent to the kidney in mammals. It is composed of an outer cortex, and a central medulla, each involved in different hormone: mediated phenomena.

ADRENALIN: A hormone produced by the pituitary that stimulates the adrenal cortex.

ADSORB: Hold on a surface.

ADSORPTION: *Not to be confused with absorption.* Adsorption is a process that occurs when a gas or liquid solute accumulates on the surface of a solid or a liquid (adsorbent), forming a film of molecules or atoms (the adsorbate). It is different from absorption, in which a substance diffuses into a liquid or solid to form a solution. The term sorption encompasses both processes, while desorption is the reverse process. Adsorption is present in many natural physical, biological, and chemical systems, and is widely used in industrial applications such as activated charcoal, synthetic resins, and water purification. Adsorption, ion exchange, and chromatography are sorption processes in which certain adsorbates are selectively transferred from the fluid phase to the surface of insoluble, rigid particles suspended in a vessel or packed in a column. Similar to surface tension, adsorption is a consequence of surface energy. In a bulk material, all the bonding requirements (be they ionic, covalent, or metallic) of the constituent atoms of the material are filled by other atoms in the material. However, atoms on the surface of the adsorbent are not wholly surrounded by other adsorbent atoms, and therefore can attract adsorbates. The exact nature of the bonding depends on the details of the species involved, but the adsorption process is generally classified as physisorption (characteristic of weak van der Waals forces) or chemisorption (characteristic of covalent bonding).

ADVANCED: New, unlike the ancestral condition.

AERATION: The addition of air or oxygen to water or wastewater, usually by mechanical means, to increase dissolved oxygen levels and maintains aerobic conditions.

AEROBIC: The condition of requiring oxygen; an aerobe is an organism which can live and grow only in the presence of oxygen.

AEROBIC DIGESTION: Sludge stabilization process involving direct oxidation of biodegradable matter and oxidation of microbial cellular material.

AGE STRUCTURE: The relative numbers of individuals of each age in a population.

AGNATHAN: A member of a jawless class of vertebrates represented today by the lampreys and hagfishes.

AGONISTIC BEHAVIOR: A type of behavior involving a contest of some kind that determines which competitor gains access to some resource, such as food or mates.

AIDS (acquired immune deficiency syndrome): A condition in which the body's helper T lymphocytes are destroyed, leaving the victim subject to opportunistic diseases.

AIR GAP SEPARATION: A physical separation space that is present between the discharge vessel and the receiving vessel; for an example, a kitchen faucet.

AIR ENTRAINMENT: The dissolution or inclusion of air bubbles into water.

ALCOHOL: Any of a class of organic compounds in which one or more - OH groups are attached to a carbon compound.

ALDEHYDE: An organic molecule with a carbonyl group located at the end of the carbon skeleton.

ALGAE: Microscopic plants that are free-living and usually live in water. They occur as single cells floating in water, or as multicellular plants like seaweed or strands of algae that attach to rocks.

ALPHA AND BETA RADIOACTIVITY: Represent two common forms of radioactive decay. Radioactive elements have atomic nuclei so heavy that the nucleus will break apart, or disintegrate spontaneously. When decay occurs, high-energy particles are released. These high-energy particles are called radioactivity. Although radioactivity from refined radioactive elements can be dangerous, it is rare to find dangerous levels of radioactivity in natural waters. An alpha particle is a doubly-charged helium nucleus comprised of two protons, two neutrons, and no electrons. A beta particle is a high-speed electron. Alpha particles do not penetrate matter easily, and are stopped by a piece of paper. Beta particles are much more penetrating and can pass through a millimeter of lead.

ALKALINE: Having a pH of more than 7. Alkaline solutions are also said to be basic.

ALKALINITY: Alkalinity or AT is a measure of the ability of a solution to neutralize acids to the equivalence point of carbonate or bicarbonate. Alkalinity is closely related to the acid neutralizing capacity (ANC) of a solution and ANC is often incorrectly used to refer to alkalinity. However, the acid neutralizing capacity refers to the combination of the solution and solids present (e.g., suspended matter, or aquifer solids), and the contribution of solids can dominate the ANC (see carbonate minerals below). The alkalinity is equal to the stoichiometric sum of the bases in solution. In the natural environment carbonate alkalinity tends to make up most of the total alkalinity due to the common occurrence and dissolution of carbonate rocks and presence of carbon dioxide in the atmosphere. Other common natural components that can contribute to alkalinity include borate, hydroxide, phosphate, silicate, nitrate, dissolved ammonia, the conjugate bases of some organic acids and sulfide. Solutions produced in a laboratory may contain a virtually limitless number of bases that contribute to alkalinity. Alkalinity is usually given in the unit mEq/L (milliequivalent per liter). Commercially, as in the pool industry, alkalinity might also be given in the unit ppm or parts per million. Alkalinity is sometimes incorrectly used interchangeably with basicity. For example, the pH of a solution can be lowered by the addition of CO₂. This will reduce the basicity; however, the alkalinity will remain unchanged.

ALLANTOIS: One of the four extraembryonic membranes found associated with developing vertebrates; it serves in gas exchange and as a repository for the embryo's nitrogenous waste. In humans, the allantois is involved in early blood formation and development of the urinary bladder.

ALLELE: Alternate forms of a gene which may be found at a given location (locus) on members of a homologous set of chromosomes. Structural variations between alleles may lead to different phenotypes for a given trait.

ALLOMETRIC: The variation in the relative rates of growth of various parts of the body, which helps shape the organism.

ALLOPATRIC SPECIATION: A type of speciation which occurs when a population becomes segregated into two populations by some sort of geographic barrier (also called geographic speciation). This phenomenon is presumed to have been the mechanism whereby many species of organisms evolved.

ALLOPOLYPLOID: A common type of polyploid species resulting from two different species interbreeding and combining their chromosomes.

ALL-OR-NONE: (event) An action that occurs either completely or not at all, such as the generation of an action potential by a neuron.

ALLOSTERIC ENZYME: An enzyme that can exist in two or more conformations.

ALLOSTERIC SITE: A receptor on an enzyme molecule which is remote from the active site. Binding of the appropriate molecule to the allosteric site changes the conformation of the active site, making it either more or less receptive to the substrate.

ALPHA HELIX: A spiral shape constituting one form of the secondary structure of proteins, arising from a specific hydrogen bonding structure.

ALTERNATION OF GENERATIONS: Occurrences of a multicellular diploid form, the sporophyte, with a multicellular haploid form, the gametophyte.

ALTERNATIVE DISINFECTANTS: Disinfectants - other than chlorination (halogens) - used to treat water, e.g. ozone, ultraviolet radiation, chlorine dioxide, and chloramine. There is limited experience and scientific knowledge about the by-products and risks associated with the use of alternatives.

ALTRUISM: The willingness of an individual to sacrifice its fitness for the benefit of another.

ALUMINUM SULFATE: The chemical name for Alum. The molecular formula of Alum is $\text{Al}_2(\text{SO}_4)_3 \cdot 14\text{H}_2\text{O}$. It is a cationic polymer.

ALVEOLUS: One of the dead-end, multilobed air sacs that constitute the gas exchange surface of the lungs.

AMINO ACID: An organic molecule possessing a carboxyl (COOH) and amino group. Amino acids serve as the monomers of polypeptides and proteins.

AMINO GROUP: A functional group consisting of a nitrogen atom bonded to two hydrogens; can act as a base in solution, accepting a hydrogen ion and acquiring a charge of +1.

AMINOACYL: tRNA synthetases- A family of enzymes, at least one for each amino acid, that catalyze the attachment of an amino acid to its specific tRNA molecule.

AMOEBA: Amoeba (sometimes amoeba or ameba, plural amoebae) is a genus of protozoa that moves by means of pseudopods, and is well-known as a representative unicellular organism. The word amoeba or ameba is variously used to refer to it and its close relatives, now grouped as the Amoebozoa, or to all protozoa that move using pseudopods, otherwise termed amoeboids.

AMOEBOID: (cell) A cell which has the tendency to change shape by protoplasmic flow. (movement) A streaming locomotion characteristic of Amoeba and other protists, as well as some individual cells, such as white blood cells, in animals.

AMMONIA: A chemical made with Nitrogen and Hydrogen and used with chlorine to disinfect water. Most ammonia in water is present as the ammonium ion rather than as ammonia.

AMP (Adenosine monophosphate): A singly phosphorylated organic compound that can be further phosphorylated to form ADP.

AMYLASE: A starch-digesting enzyme.

ANABOLISM: A metabolic pathway of biosynthesis that consumes energy to build a large molecule from simpler ones.

ANAEROBIC: Without oxygen. An organism which lives in the absence of oxygen is called an anaerobe. An abnormal condition in which color and odor problems are most likely to occur.

ANAEROBIC CONDITIONS: When anaerobic conditions exist in either the metalimnion or hypolimnion of a stratified lake or reservoir, water quality problems may make the water unappealing for domestic use without costly water treatment procedures. Most of these problems are associated with Reduction in the stratified waters.

ANAEROBIC DIGESTION: Sludge stabilization process where the organic material in biological sludges are converted to methane and carbon dioxide in an airtight reactor.

ANAGENESIS: A pattern of evolutionary change involving the transformation of an entire population, sometimes to a state different enough from the ancestral population to justify renaming it as a separate species; also called phyletic.

ANALOGOUS: Characteristics of organisms which are similar in function (and often in structure) but different in embryological and/or evolutionary origins.

ANALYST: The analyst must have at least 2 years of college lecture and laboratory course work in microbiology or a closely related field. The analyst also must have at least 6 months of continuous bench experience with environmental protozoa detection techniques and IFA microscopy, and must have successfully analyzed at least 50 water and/or wastewater samples for *Cryptosporidium* and *Giardia*. Six months of additional experience in the above areas may be substituted for two years of college.

ANCESTRAL TRAIT: Trait shared by a group of organisms as a result of descent from a common ancestor.

ANEUPLOIDY: A chromosomal aberration in which certain chromosomes are present in extra copies or are deficient in number.

ANION: A negatively charged ion.

ANISOGAMOUS: Reproducing by the fusion of gametes that differ only in size, as opposed to gametes that are produced by oogamous species. Gametes of oogamous species, such as egg cells and sperm, are highly differentiated.

ANNUAL: A plant that completes its entire life cycle in a single year or growing season.

ANOXIC: A biological environment that is deficient in molecular oxygen, but may contain chemically bound oxygen, such as nitrates and nitrites.

ANTERIOR: Referring to the head end of a bilaterally symmetrical animal.

ANTHROPOMORPHISM: Attributing a human characteristic to an inanimate object or a species other than a human.

ANTIBIOTIC: A chemical that kills or inhibits the growth of bacteria, often via transcriptional or translational regulation.

ANTIBODY: A protein, produced by the B lymphocytes of the immune system that binds to a particular antigen.

ANTICODON: The specialized base triplet on one end of a tRNA molecule that associates with a particular complementary codon on an mRNA molecule during protein synthesis.

ANTIDIURETIC HORMONE: A hormone important in osmoregulation (it acts to reduce the elimination of water from the body).

ANTIGEN: A foreign macromolecule that does not belong to the host organism and that elicits an immune response.

APOMORPHIC CHARACTER: A derived phenotypic character, or homology, that evolved after a branch diverged from a phylogenetic tree.

APOSEMATIC COLORATION: Serving as a warning, with reference particularly to colors and structures that signal possession of defensive device.

AQUEOUS SOLUTION: A solution in which water is the solvent.

ARCHAEBACTERIA: A lineage of prokaryotes, represented today by a few groups of bacteria inhabiting extreme environments. Some taxonomists place archaeobacteria in their own kingdom, separate from the other bacteria.

ARCHENTERON: The endoderm-lined cavity formed during the gastrulation process that develops into the digestive tract of the animal.

ARISTOTLE: A Greek philosopher often credited as the first to use empirical and deductive methods in logic.

ARTIFICIAL SELECTION: The selective breeding of domesticated plants and animals to encourage the occurrence of desirable traits.

AS: The chemical symbol of Arsenic.

AS NITROGEN: An expression that tells how the concentration of a chemical is expressed mathematically. The chemical formula for the nitrate ion is NO_3^- , with a mass of 62. The concentration of nitrate can be expressed either in terms of the nitrate ion or in terms of the principal element, nitrogen. The mass of the nitrogen atom is 14. The ratio of the nitrate ion mass to the nitrogen atom mass is 4.43. Thus a concentration of 10 mg/L nitrate expressed as nitrogen would be equivalent to a concentration of 44.3 mg/L nitrate expressed as nitrate ion. When dealing with nitrate numbers it is very important to know how numeric values are expressed.

ASCUS: The elongate spore sac of a fungus of the Ascomycota group.

ASEXUAL: A type of reproduction involving only one parent that produces genetically identical offspring by budding or division of a single cell or the entire organism into two or more parts.

ASSORTATIVE MATING: A type of nonrandom mating in which mating partners resemble each other in certain phenotypic characters.

ASYMMETRIC CARBON: A carbon atom covalently bonded to four different atoms or groups of atoms.

ATOM: The general definition of an ion is an atom with a positive or negative charge. Electron is the name of a negatively charged atomic particle.

ATOMIC NUMBER: The number of protons in the nucleus of an atom, unique for each element.

ATOMIC THEORY: The physical theory of the structure, properties and behavior of the atom.

ATOMIC WEIGHT: The total atomic mass, which is the mass in grams of one mole of the atom (relative to that of ^{12}C , which is designated as 12).

ATP (Adenosine triphosphate): A triply phosphorylated organic compound that functions as "energy currency" for organisms, thus allowing life forms to do work; it can be hydrolyzed in two steps (first to ADP and then to AMP) to liberate 7.3 Kcal of energy per mole during each hydrolysis.

ATPASE: An enzyme that functions in producing or using ATP.

AUTOGENOUS MODEL: A hypothesis which suggests that the first eukaryotic cells evolved by the specialization of internal membranes originally derived from prokaryotic plasma membranes.

AUTOIMMUNE DISEASE: An immunological disorder in which the immune system goes awry and turns against itself.

AUTONOMIC NERVOUS SYSTEM: A subdivision of the motor nervous system of vertebrates that regulates the internal environment; consists of the sympathetic and parasympathetic subdivisions.

AUTOPOLYPLOID: A type of polyploid species resulting from one species doubling its chromosome number to become tetraploids, which may self-fertilize or mate with other tetraploids.

AUTOSOME: Chromosomes that are not directly involved in determining sex.

AUTOTROPH: An organism which is able to make organic molecules from inorganic ones either by using energy from the sun or by oxidizing inorganic substances.

AUXIN: One of several hormone compounds in plants that have a variety of effects, such as phototropic response through stimulation of cell elongation, stimulation of secondary growth, and development of leaf traces and fruit.

AUXOTROPH: A nutritional mutant that is unable to synthesize and that cannot grow on media lacking certain essential molecules normally synthesized by wild-type strains of the same species.

AXON: A typically long outgrowth, or process, from a neuron that carries nerve impulses away from the cell body toward target cells.

AXONEME: An internal flagellar structure that occurs in some protozoa, such as *Giardia*, *Spironucleus*, and *Trichomonas*.

B-CELL LYMPHOCYTE: A type of lymphocyte that develops in the bone marrow and later produces antibodies, which mediate humoral immunity.

BACKFLOW: To reverse the natural and normal directional flow of a liquid, gases, or solid substances back in to the public potable (drinking) water supply. This is normally an undesirable effect.

BACKFLOW PREVENTION: To stop or prevent the occurrence of, the unnatural act of reversing the normal direction of the flow of liquid, gases, or solid substances back in to the public potable (drinking) water supply. See Cross-connection control.

BACKSIPHONAGE: A liquid substance that is carried over a higher point. It is the method by which the liquid substance may be forced by excess pressure over or into a higher point.

BACTERIA: Small, one-celled animals too small to be seen by the naked eye. Bacteria are found everywhere, including on and in the human body. Humans would be unable to live without the bacteria that inhabit the intestines and assist in digesting food. Only a small percentage of bacteria cause disease in normal, healthy humans. Other bacteria can cause infections if they get into a cut or wound. Bacteria are the principal concern in evaluating the microbiological quality of drinking water, because some of the bacteria-caused diseases that can be transmitted by drinking water are potentially life-threatening.

BACTERIOPHAGE: A bacteriophage (from 'bacteria' and Greek phagein, 'to eat') is any one of a number of viruses that infect bacteria. The term is commonly used in its shortened form, phage. Typically, bacteriophages consist of an outer protein hull enclosing genetic material. The genetic material can be ssRNA (single stranded RNA), dsRNA, ssDNA, or dsDNA between 5 and 500 kilo base pairs long with either circular or linear arrangement. Bacteriophages are much smaller than the bacteria they destroy - usually between 20 and 200 nm in size.

BACTERIUM: A unicellular microorganism of the Kingdom Monera. Bacteria are prokaryotes; their cells have no true nucleus. Bacteria are classified into two groups based on a difference in cell walls, as determined by Gram staining.

BALANCED POLYMORPHISM: A type of polymorphism in which the frequencies of the coexisting forms do not change noticeably over many generations.

BARR BODY: The dense object that lies along the inside of the nuclear envelope in cells of female mammals, representing the one inactivated X chromosome.

BASAL BODY: A cell structure identical to a centriole that organizes and anchors the microtubule assembly of a cilium or flagellum.

BASE PAIRING: Complementary base pairing refers to the chemical affinities between specific base pairs in a nucleic acid: adenine always pairs with thymine, and guanine always pairs with cytosine. In pairing between DNA and RNA, the uracil of RNA always pairs with adenine. Complementary base pairing is not only responsible for the DNA double helix, but it is also essential for various in vitro techniques such as PCR (polymerase chain reaction). Complementary base pairing is also known as Watson-Crick pairing.

BASE: A substance that reduces the hydrogen ion concentration in a solution.

BASEMENT MEMBRANE: The floor of an epithelial membrane on which the basal cells rest.

BASIDIUM: The spore-bearing structure of Basidiomycota.

BATESIAN MIMICRY: A type of mimicry in which a harmless species looks like a different species that is poisonous or otherwise harmful to predators.

BEHAVIORAL ECOLOGY: A heuristic approach based on the expectation that Darwinian fitness (reproductive success) is improved by optimal behavior.

BELT PRESS: A dewatering device utilizing two opposing synthetic fabric belts, revolving over a series of rollers to “squeeze” water from the sludge.

BENIGN TUMOR: A noncancerous abnormal growth composed of cells that multiply excessively but remain at their place of origin in the body.

BENTHIC: Pertaining to the bottom region of an aquatic environment.

BENCH TEST: A small-scale test or study used to determine whether a technology is suitable for a particular application.

BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE (BAT): A level of technology based on the best existing control and treatment measures that are economically achievable within the given industrial category or subcategory.

BEST MANAGEMENT PRACTICES (BMPs): Schedules of activities, prohibitions of practices, maintenance procedures, and other management practices to prevent or reduce the pollution of waters of the U.S. BMPs also include treatment requirements, operating procedures and practices to control plant site runoff, spillage or leaks, sludge or waste disposal, or drainage from raw material storage.

BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE (BPT):

A level of technology represented by the average of the best existing wastewater treatment performance levels within an industrial category or subcategory.

BEST PROFESSIONAL JUDGMENT (BPJ): The method used by a permit writer to develop technology-based limitations on a case-by-case basis using all reasonably available and relevant data.

BETA PLEATED SHEET: A zigzag shape, constituting one form of the secondary structure of proteins formed of hydrogen bonds between polypeptide segments running in opposite directions.

BILATERAL SYMMETRY: The property of having two similar sides, with definite upper and lower surfaces and anterior and posterior ends. The Bilateria are members of the branch of Eumetazoa (Kingdom Animalia) which possess bilateral symmetry.

BILE: A mixture of substances containing bile salts, which emulsify fats and aid in their digestion and absorption.

BINARY FISSION: The kind of cell division found in prokaryotes, in which dividing daughter cells each receive a copy of the single parental chromosome.

BINOMIAL NOMENCLATURE: Consisting of two names. In biology, each organism is given a *genus* name and a species name (i.e., the human is *Homo sapiens*).

BIOCHEMICAL OXYGEN DEMAND (BOD): The BOD test is used to measure the strength of wastewater. The BOD of wastewater determines the milligrams per liter of oxygen required during stabilization of decomposable organic matter by aerobic bacteria action. Also, the total milligrams of oxygen required over a five-day test period to biologically assimilate the organic contaminants in one liter of wastewater maintained at 20 degrees Centigrade.

BIOGENESIS: A central concept of biology, that living organisms are derived from other living organisms (contrasts to the concept of abiogenesis, or spontaneous generation, which held that life could be derived from inanimate material).

BIOGEOCHEMICAL CYCLE: A circuit whereby a nutrient moves between both biotic and abiotic components of ecosystems.

BIOGEOGRAPHY: The study of the past and present distribution of species.

BIOLOGICAL MAGNIFICATION: Increasing concentration of relatively stable chemicals as they are passed up a food chain from initial consumers to top predators.

BIOLOGICAL SPECIES: A population or group of populations whose members have the potential to interbreed. This concept was introduced by Ernst Mayr.

BIOMASS: The total weight of all the organisms, or of a designated group of organisms, in a given area

BIOME: A large climatic region with characteristic sorts of plants and animals.

BIOSOLIDS: Solid organic matter recovered from municipal wastewater treatment that can be beneficially used, especially as a fertilizer. "Biosolids" are solids that have been stabilized within the treatment process, whereas "sludge" has not.

BIOSPHERE: The region on and surrounding the earth which is capable of supporting life. Theoretically, the concept may be ultimately expanded to include other regions of the universe.

BMR: The basal metabolic rate is the minimal energy (in kcal) required by a homeotherm to fuel itself for a given time. Measured within the thermoneutral zone for a postabsorptive animal at rest.

BODY FEED: Coating or bulking material added to the influent of material to be treated. This adds "body" to the material during filtration cycle.

BREAK POINT CHLORINATION: The process of chlorinating the water with significant quantities of chlorine to oxidize all contaminants and organic wastes and leave all remaining chlorine as free chlorine.

BROMINE: Chemical disinfectant (HALOGEN) that kills bacteria and algae. This chemical disinfectant has been used only on a very limited scale for water treatment because of its handling difficulties. This chemical causes skin burns on contact, and a residual is difficult to obtain.

BUFFER: Chemical that resists pH change, e.g. sodium bicarbonate

BULKING SLUDGE: A poor or slow settling activated sludge that results from the prevalence of filamentous organisms.

BULKING SLUDGE: A phenomenon that occurs in activated sludge plants whereby the sludge occupies excessive volumes and will not concentrate readily. This condition refers to a decrease in the ability of the sludge to settle and consequent loss over the settling tank weir. Bulking in activated sludge aeration tanks is caused mainly by excess suspended solids (SS) content. Sludge bulking in the final settling tank of an activated sludge plant may be caused by improper balance of the BOD load, SS concentration in the mixed liquor, or the amount of air used in aeration.

Ca: The chemical symbol for calcium.

CADMIUM: A contaminant that is usually not found naturally in water or in very small amounts.

CAKE: Dewatered sludge material with a satisfactory solids concentration to allow handling as a solid material.

CALCIUM HARDNESS: A measure of the calcium salts dissolved in water.

CALCIUM ION: Is divalent because it has a valence of +2.

CALCIUM, MAGNESIUM AND IRON: The three elements that cause hardness in water.

CaOCl₂·4H₂O: The molecular formula of Calcium hypochlorite.

CARBON DIOXIDE GAS: The pH will decrease and alkalinity will change as measured by the Langelier index after pumping carbon dioxide gas into water.

CARBONATE HARDNESS: Carbonate hardness is the measure of Calcium and Magnesium and other hard ions associated with carbonate (CO₃²⁻) and bicarbonate (HCO₃⁻) ions contained in a solution, usually water. It is usually expressed either as parts per million (ppm or mg/L), or in degrees (KH - from the German "Karbonathärte"). One German degree of carbonate hardness is equivalent to about 17.8575 mg/L.

Both measurements (mg/L or KH) are usually expressed "as CaCO₃" – meaning the amount of hardness expressed as if calcium carbonate was the sole source of hardness. Every bicarbonate ion only counts for half as much carbonate hardness as a carbonate ion does. If a solution contained 1 liter of water and 50 mg NaHCO₃ (baking soda), it would have a carbonate hardness of about 18 mg/L as CaCO₃. If you had a liter of water containing 50 mg of Na₂CO₃, it would have a carbonate hardness of about 29 mg/L as CaCO₃. Carbonate hardness supplements non-carbonate (a.k.a. "permanent") hardness where hard ions are associated with anions such as Chloride that do not precipitate out of solution when heated. Carbonate hardness is removed from water through the process of softening. Softening can be achieved by adding lime in the form of Ca(OH)₂, which reacts first with CO₂ to form calcium carbonate precipitate, reacts next with multi-valent cations to remove carbonate hardness, then reacts with anions to replace the non-carbonate hardness due to multi-valent cations with non-carbonate hardness due to calcium. The process requires recarbonation through the addition of carbon-dioxide to lower the pH which is raised during the initial softening process.

CARBONATE, BICARBONATE AND HYDROXIDE: Chemicals that are responsible for the alkalinity of water.

CAROLUS LINNAEUS: Swedish botanist and originator of the binomial nomenclature system of taxonomic classification

CATHODIC PROTECTION: An operator should protect against corrosion of the anode and/or the cathode by painting the copper cathode. Cathodic protection interrupts corrosion by supplying an electrical current to overcome the corrosion-producing mechanism. Guards against stray current corrosion.

CAUSTIC: NaOH (also called Sodium Hydroxide) is a strong chemical used in the treatment process to neutralize acidity, increase alkalinity or raise the pH value.

CAUSTIC SODA: Also known as sodium hydroxide and is used to raise pH.

CENTRATE: The liquid remaining after solids have been removed in a centrifuge.

CENTRIFUGE: A dewatering device relying on centrifugal force to separate particles of varying density such as water and solids.

CENTRIFUGAL FORCE: That force when a ball is whirled on a string that pulls the ball outward. On a centrifugal pump, it is that force which throws water from a spinning impeller.

CENTRIFUGAL PUMP: A pump consisting of an impeller fixed on a rotating shaft and enclosed in a casing, having an inlet and a discharge connection. The rotating impeller creates pressure in the liquid by the velocity derived from centrifugal force.

CHAIN OF CUSTODY (COC): A record of each person involved in the possession of a sample from the person who collects the sample to the person who analyzes the sample in the laboratory.

CHECK VALVE: Allows water to flow in only one direction.

CHELATION: A chemical process used to control scale formation in which a chelating agent "captures" scale-causing ions and holds them in solution.

CHEMICAL FEED RATE: Chemicals are added to the water in order to improve the subsequent treatment processes. These may include pH adjusters and coagulants. Coagulants are chemicals, such as alum, that neutralize positive or negative charges on small particles, allowing them to stick together and form larger particles that are more easily removed by sedimentation (settling) or filtration. A variety of devices, such as baffles, static mixers, impellers and in-line sprays, can be used to mix the water and distribute the chemicals evenly.

CHEMICAL OXIDIZER: KMnO_4 is used for taste and odor control because it is a strong oxidizer which eliminates many organic compounds.

CHEMICAL REACTION RATE: In general, when the temperature decreases, the chemical reaction rate also decreases. The opposite is true for when the temperature increases.

CHEMICAL SLUDGE: Sludge resulting from chemical treatment processes of inorganic wastes that are not biologically active.

CHEMICAL OXYGEN DEMAND (COD): The milligrams of oxygen required to chemically oxidize the organic contaminants in one liter of wastewater.

CHLORAMINATION: Treating drinking water by applying chlorine before or after ammonia. This creates a persistent disinfectant residual called chloramines.

CHLORAMINES: A group of chlorine ammonia compounds formed when chlorine combines with organic wastes in the water. Chloramines are not effective as disinfectants and are responsible for eye and skin irritation as well as strong chlorine odors (also known as Combined Chlorine).

CHLORINATION: The process in water treatment of adding chlorine (gas or solid hypochlorite) for purposes of disinfection.

CHLORINE: A chemical used to disinfect water. Chlorine is extremely reactive, and when it comes in contact with microorganisms in water it kills them. Chlorine is added to swimming pools to keep the water safe for swimming. Chlorine is available as solid tablets for swimming pools. Some public water system's drinking water treatment plants use chlorine in a gas form because of the large volumes required. Chlorine is very effective against algae, bacteria and viruses. Protozoa are resistant to chlorine because they have thick coats; protozoa are removed from drinking water by filtration.

CHLORINE DEMAND: Amount of chlorine required to react on various water impurities before a residual is obtained. Also, means the amount of chlorine required to produce a free chlorine residual of 0.1 mg/l after a contact time of fifteen minutes as measured by iodometric method of a sample at a temperature of twenty degrees in conformance with Standard methods.

CHLORINE FEED: Chlorine may be delivered by vacuum-controlled solution feed chlorinators. The chlorine gas is controlled, metered, introduced into a stream of injector water and then conducted as a solution to the point of application.

CHLORINE, FREE: Chlorine available to kill bacteria or algae. The amount of chlorine available for sanitization after the chlorine demand has been met. Also known as chlorine residual.

CIRCULATION: The continual flow of drilling fluid from injection to recovery and recirculation at the surface.

ClO₂: The molecular formula of Chlorine dioxide.

CLARIFIER: A settling tank used to remove suspended solids by gravity settling. Commonly referred to as sedimentation or settling basins, they are usually equipped with a motor driven chain and flight or rake mechanism to collect settled sludge and move it to a final removal point.

COMPOSITE SAMPLE: To have significant meaning, samples for laboratory tests on wastewater should be representative of the wastewater. The best method of sampling is proportional composite sampling over several hours during the day. Composite samples are collected because the flow and characteristics of the wastewater are continually changing. A composite sample will give a representative analysis of the wastewater conditions.

COAGULATION: The best pH range for coagulation is between 5 and 7. Mixing is an important part of the coagulation process you want to complete the coagulation process as quickly as possible. A chemical added to initially destabilize, aggregate, and bind together colloids and emulsions to improve settleability, filterability, or drainability.

COLIFORM: Bacteria normally found in the intestines of warm-blooded animals. Coliform bacteria are present in high numbers in animal feces. They are an indicator of potential contamination of water. Adequate and appropriate disinfection effectively destroys coliform bacteria. Public water systems are required to deliver safe and reliable drinking water to their customers 24 hours a day, 365 days a year. If the water supply becomes contaminated, consumers can become seriously ill. Fortunately, public water systems take many steps to ensure that the public has safe, reliable drinking water. One of the most important steps is to regularly test the water for coliform bacteria. Coliform bacteria are organisms that are present in the environment and in the feces of all warm-blooded animals and humans. Coliform bacteria will not likely cause illness. However, their presence in drinking water indicates that disease-causing organisms (pathogens) could be in the water system. Most pathogens that can contaminate water supplies come from the feces of humans or animals. Testing drinking water for all possible pathogens is complex, time-consuming, and expensive. It is relatively easy and inexpensive to test for coliform bacteria. If coliform bacteria are found in a water sample, water system operators work to find the source of contamination and restore safe drinking water. There are three different groups of coliform bacteria; each has a different level of risk.

COLIFORM TESTING: The effectiveness of disinfection is usually determined by Coliform bacteria testing. A positive sample is a bad thing and indicates that you have bacteria contamination.

COLLOIDAL SUSPENSIONS: Because both iron and manganese react with dissolved oxygen to form insoluble compounds, they are not found in high concentrations in waters containing dissolved oxygen except as colloidal suspensions of the oxide.

COLORIMETRIC MEASUREMENT: A means of measuring an unknown chemical concentration in water by measuring a sample's color intensity.

CHRONIC: A stimulus that lingers or continues for a relatively long period of time, often one-tenth of the life span or more. Chronic should be considered a relative term depending on the life span of an organism. The measurement of chronic effect can be reduced growth, reduced reproduction, etc., in addition to lethality.

COMBINED CHLORINE: The reaction product of chlorine with ammonia or other pollutants, also known as chloramines.

COMPOSITE SAMPLE: A water sample that is a combination of a group of samples collected at various intervals during the day. A combination of individual samples of water or wastewater taken at predetermined intervals to minimize the effect of variability of individual samples.

COMPOSTING: Stabilization process relying on the aerobic decomposition of organic matter in sludge by bacteria and fungi.

CONDENSATION: The process that changes water vapor to tiny droplets or ice crystals.

CONTACT STABILIZATION PROCESS: Modification of the activated sludge process where raw wastewater is aerated with activated sludge for a short time prior to solids removal and continued aeration in a stabilization tank.

CONTACT TIME: If the water temperature decreases from 70°F (21°C) to 40°F (4°C). The operator needs to increase the detention time to maintain good disinfection of the water.

CONTAINS THE ELEMENT CARBON: A simple definition of an organic compound.

CONTAMINANT: Any natural or man-made physical, chemical, biological, or radiological substance or matter in water, which is at a level that may have an adverse effect on public health, and which is known or anticipated to occur in public water systems.

CONTAMINATE:

1. To make impure or unclean by contact or mixture.
2. To expose to or permeate with radioactivity.

CONTAMINATION: A degradation in the quality of groundwater in result of the it's becoming polluted with unnatural or previously non-existent constituents.

COPPER: The chemical name for the symbol Cu.

CORROSION: The removal of metal from copper, other metal surfaces and concrete surfaces in a destructive manner. Corrosion is caused by improperly balanced water or excessive water velocity through piping or heat exchangers.

CORROSIVITY: The Langelier Index measures corrosivity.

CROSS-CONNECTION: A physical connection between a public water system and any source of water or other substance that may lead to contamination of the water provided by the public water system through backflow. Might be the source of an organic substance causing taste and odor problems in a water distribution system.

CROSS-CONTAMINATION: The mixing of two unlike qualities of water. For example, the mixing of good water with a polluting substance like a chemical.

CRYPTOSPORIDIUM: A disease-causing parasite, resistant to chlorine disinfection. It may be found in fecal matter or contaminated drinking water. Cryptosporidium is a protozoan pathogen of the Phylum Apicomplexa and causes a diarrheal illness called cryptosporidiosis. Other apicomplexan pathogens include the malaria parasite Plasmodium, and Toxoplasma, the causative agent of toxoplasmosis. Unlike Plasmodium, which transmits via a mosquito vector, Cryptosporidium does not utilize an insect vector and is capable of completing its life cycle within a single host, resulting in cyst stages which are excreted in feces and are capable of transmission to a new host.

CYANURIC ACID: Chemical used to prevent the decomposition of chlorine by ultraviolet (UV) light.

CYANOBACTERIA: Cyanobacteria, also known as blue-green algae, blue-green bacteria or Cyanophyta, is a phylum of bacteria that obtain their energy through photosynthesis. The name "cyanobacteria" comes from the color of the bacteria (Greek: kyanós = blue). They are a significant component of the marine nitrogen cycle and an important primary producer in many areas of the ocean, but are also found on land.

CYST: A phase or a form of an organism produced either in response to environmental conditions or as a normal part of the life cycle of the organism. It is characterized by a thick and environmentally resistant cell wall.

DAILY MAXIMUM LIMITATIONS: The maximum allowable discharge of pollutants during a 24 hour period. Where daily maximum limitations are expressed in units of mass, the daily discharge is the total mass discharged over the course of the day. Where daily maximum limitations are expressed in terms of a concentration, the daily discharge is the arithmetic average measurement of the pollutant concentration derived from all measurements taken that day.

DANGEROUS CHEMICALS: The most suitable protection when working with a chemical that produces dangerous fumes is to work under an air hood.

DECANT: Separation of a liquid from settled solids by removing the upper layer of liquid after the solids have settled.

DECIBELS: The unit of measurement for sound.

DECOMPOSE: To decay or rot.

DECOMPOSITION OF ORGANIC MATERIAL: The decomposition of organic material in water produces taste and odors.

DEMINERALIZATION PROCESS: Mineral concentration of the feed water is the most important consideration in the selection of a demineralization process. Acid feed is the most common method of scale control in a membrane demineralization treatment system.

DENITRIFICATION: A biological process by which nitrate is converted to nitrogen gas.

DEPOLARIZATION: The removal of hydrogen from a cathode.

DESICCANT: When shutting down equipment which may be damaged by moisture, the unit may be protected by sealing it in a tight container. This container should contain a desiccant.

DESORPTION: Desorption is a phenomenon whereby a substance is released from or through a surface. The process is the opposite of sorption (that is, adsorption and absorption). This occurs in a system being in the state of sorption equilibrium between bulk phase (fluid, i.e. gas or liquid solution) and an adsorbing surface (solid or boundary separating two fluids). When the concentration (or pressure) of substance in the bulk phase is lowered, some of the sorbed substance changes to the bulk state. In chemistry, especially chromatography, desorption is the ability for a chemical to move with the mobile phase. The more a chemical desorbs, the less likely it will adsorb, thus instead of sticking to the stationary phase, the chemical moves up with the solvent front. In chemical separation processes, stripping is also referred to as desorption as one component of a liquid stream moves by mass transfer into a vapor phase through the liquid-vapor interface.

DIATOMACEOUS EARTH: A fine silica material containing the skeletal remains of algae.

DIGESTER: A tank or vessel used for sludge digestion.

DIGESTION: The biological decomposition of organic matter in sludge resulting in partial gasification, liquefaction, and mineralization of putrescible and offensive solids.

DIRECT CURRENT: A source of direct current (**DC**) may be used for standby lighting in a water treatment facility. The electrical current used in a DC system may come from a battery.

DISINFECT: The application of a chemical to kill most, but not all, microorganisms that may be present. Chlorine is added to public water drinking systems drinking water for disinfection. Depending on your state rule, drinking water must contain a minimum of 0.2 mg/L free chlorine. Disinfection makes drinking water safe to consume from the standpoint of killing pathogenic microorganisms including bacteria and viruses. Disinfection does not remove all bacteria from drinking water, but the bacteria that can survive disinfection with chlorine are not pathogenic bacteria that can cause disease in normal healthy humans.

DISINFECTION: The treatment of water to inactivate, destroy, and/or remove pathogenic bacteria, viruses, protozoa, and other parasites.

DISSOLVED OXYGEN: Can be added to zones within a lake or reservoir that would normally become anaerobic during periods of thermal stratification.

DISSOLVED SOLIDS: Solids in solution that cannot be removed by filtration with a 0.45 micron filter.

DISTILLATION, REVERSE OSMOSIS AND FREEZING: Processes that can be used to remove minerals from the water.

DRY ACID: A granular chemical used to lower pH and or total alkalinity.

E. COLI, *Escherichia coli*: A bacterium commonly found in the human intestine. For water quality analyses purposes, it is considered an indicator organism. These are considered evidence of water contamination. Indicator organisms may be accompanied by pathogens, but do not necessarily cause disease themselves.

ECDYSONE: A steroid hormone that triggers molting in arthropods.

ECOLOGICAL EFFICIENCY: The ratio of net productivity at one trophic level to net productivity at the next lower level.

ECOLOGICAL NICHE: The sum total of an organism's utilization of the biotic and abiotic resources of its environment. The fundamental niche represents the theoretical capabilities and the realized niche represents the actual role.

ECOLOGY: The study of how organisms interact with their environments.

ECOSYSTEM: The sum of physical features and organisms occurring in a given area.

ECTODERM: The outermost tissue layer of an animal embryo. Also, tissue derived from an embryonic ectoderm.

ECTOTHERM: An organism that uses environmental heat and behavior to regulate its body temperature.

EDWARD JENNER: A pioneer of vaccination; used vaccination with material from cowpox lesions to protect people against smallpox.

EFFECTIVENESS OF CHLORINE: The factors which influence the effectiveness of chlorination the most are pH, turbidity and temperature. Effectiveness of Chlorine decreases occurs during disinfection in source water with excessive turbidity.

EFFECTOR: The part of an organism that produces a response to a stimulus.

EFFLUENT: Partially or completely treated water or wastewater flowing out of a basin or treatment plant.

ELECTRICAL SYNAPSE: A junction between two neurons separated only by a gap junction, in which the local currents sparking the action potential pass directly between the cells.

ELECTROCARDIOGRAM: A plot of electrical activity of the heart over the cardiac cycle; measured via multiple skin electrodes.

ELECTROCHEMICAL GRADIENT: Combined electrostatic and osmotic-concentration gradient, such as the chemiosmotic gradient of mitochondria and chloroplasts.

ELECTROGENIC PUMP: An ion transport protein generating voltage across a membrane.

ELECTROMAGNETIC SPECTRUM: The entire spectrum of radiation; ranges in wavelength from less than a nanometer to more than a kilometer.

ELECTRON: The name of a negatively charged atomic particle. A negatively charged subatomic particle of an atom or ion. In atoms, the number of electrons present is equal to the number of positively charged protons present. Hence, atoms are electrically neutral.

ELECTRON MICROSCOPE: A microscope that focuses an electron beam through a specimen, resulting in resolving power a thousandfold greater than that of a light microscope. A transmission EM is used to study the internal structure of thin sections of cells; a scanning EM is used to study the ultrastructure of surfaces.

ELECTRON TRANSPORT CHAIN: A series of enzymes found in the inner membranes of mitochondria and chloroplasts. These are involved in transport of protons and electrons either across the membrane during ATP synthesis.

ELECTRONEGATIVITY: A property exhibited by some atoms whereby the nucleus has a tendency to pull electrons toward itself.

ELECTRONIC CHARGE UNIT: The charge of one electron (1.6021×10^{-19} coulomb).

ELECTROSTATIC FORCE: The attraction between particles with opposite charges.

ELECTROSTATIC GRADIENT: The free-energy gradient created by a difference in charge between two points, generally the two sides of a membrane.

ELEMENT: Any substance that cannot be broken down into another substance by ordinary chemical means.

ELIMINATION: The release of unabsorbed wastes from the digestive tract.

EMERGENT PROPERTY: A property exhibited at one level of biological organization but not exhibited at a lower level. For example, a population exhibits a birth rate, an organism does not.

EMULSION: A suspension, usually as fine droplets of one liquid in another. A mixture made up of dissimilar elements, usually of two or more mutually insoluble liquids that would normally separate into layers based on the specific gravity of each liquid.

ENDERGONIC: A phenomenon which involves uptake of energy.

ENDOCRINE: A phenomenon which relates to the presence of ductless glands of the type typically found in vertebrates. The endocrine system involves hormones, the glands which secrete them, the molecular hormone receptors of target cells, and interactions between hormones and the nervous system.

ENDOCYTOSIS: A process by which liquids or solid particles are taken up by a cell through invagination of the plasma membrane.

ENDODERM: The innermost germ layer of an animal embryo.

ENDODERMIS: A plant tissue, especially prominent in roots, that surrounds the vascular cylinder; all endodermal cells have Casparian strips.

ENDOMEMBRANE SYSTEM: The system of membranes inside a eukaryotic cell, including the membranous vesicles which associate with membrane sheets and/or tubes.

ENDOMETRIUM: The inner lining of the uterus, which is richly supplied with blood vessels that provide the maternal part of the placenta and nourish the developing embryo.

ENDONUCLEASE: An enzyme that breaks bonds within nucleic acids. A restriction endonuclease is an enzyme that breaks bonds only within a specific sequence of bases.

ENDOPLASMIC RETICULUM: A system of membrane-bounded tubes and flattened sacs, often continuous with the nuclear envelope, found in the cytoplasm of eukaryotes. Exists as rough ER, studded with ribosomes, and smooth ER, lacking ribosomes.

ENDORPHIN: A hormone produced in the brain and anterior pituitary that inhibits pain perception.

ENDOSKELETON: An internal skeleton.

ENDOSPERM: A nutritive material in plant seeds which is triploid ($3n$) and results from the fusion of three nuclei during double fertilization.

ENDOSYMBIOTIC: 1) An association in which the symbiont lives within the host 2) A widely accepted hypothesis concerning the evolution of the eukaryotic cell: the idea that eukaryotes evolved as a result of symbiotic associations between prokaryote cells. Aerobic symbionts ultimately evolved into mitochondria; photosynthetic symbionts became chloroplasts.

ENDOTHELIUM: The innermost, simple squamous layer of cells lining the blood vessels; the only constituent structure of capillaries.

ENDOTHERMIC: In chemistry, a phenomenon in which energy is absorbed by the reactants. In physiology, this term concerns organisms whose thermal relationship with the environment is dependent substantially on internal production of heat.

ENDOTOXIN: A component of the outer membranes of certain gram-negative bacteria responsible for generalized symptoms of fever and ache.

ENERGY: The capacity to do work by moving matter against an opposing force.

ENHANCER: A DNA sequence that recognizes certain transcription factors that can stimulate transcription of nearby genes.

ENTAMOEBA HISTOLYTICA: *Entamoeba histolytica*, another water-borne pathogen, can cause diarrhea or a more serious invasive liver abscess. When in contact with human cells, these amoebae are cytotoxic. There is a rapid influx of calcium into the contacted cell, it quickly stops all membrane movement save for some surface blebbing. Internal organization is disrupted, organelles lyse, and the cell dies. The amoeba may eat the dead cell or just absorb nutrients released from the cell.

ENTERIC: Rod-shaped, gram-negative, aerobic but can live in certain anaerobic conditions; produce nitrite from nitrate, acids from glucose; include *Escherichia coli*, *Salmonella* (over 1000 types), and *Shigella*.

ENTEROVIRUS: A virus whose presence may indicate contaminated water; a virus that may infect the gastrointestinal tract of humans.

ENTROPY: A type of energy which is not biologically useful to do work (in contrast to free energy).

ENVELOPE: 1) (nuclear) The surface, consisting of two layers of membrane, that encloses the nucleus of eukaryotic cells. 2) (virus) A structure which is present on the outside of some viruses (exterior to the capsid).

ENVIRONMENT: Water, air, and land, and the interrelationship that exists among and between water, air and land and all living things. The total living and nonliving aspects of an organism's internal and external surroundings.

ENZYME: A protein, on the surface of which are chemical groups so arranged as to make the enzyme a catalyst for a chemical reaction.

EPICOTYL: A portion of the axis of a plant embryo above the point of attachment of the cotyledons; forms most of the shoot.

EPIDERMIS: The outermost portion of the skin or body wall of an animal.

EPINEPHRINE: A hormone produced as a response to stress; also called adrenaline.

EPIPHYTE: A plant that nourishes itself but grows on the surface of another plant for support, usually on the branches or trunks of tropical trees.

EPISOME: Genetic element at times free in the cytoplasm, at other times integrated into a chromosome.

EPISTASIS: A phenomenon in which one gene alters the expression of another gene that is independently inherited.

EPITHELIUM: An animal tissue that forms the covering or lining of all free body surfaces, both external and internal.

EPITOPE: A localized region on the surface of an antigen that is chemically recognized by antibodies; also called antigenic determinant.

EQUATION: A precise representation of the outcome of a chemical reaction, showing the reactants and products, as well as the proportions of each.

EQUILIBRIUM: In a reversible reaction, the point at which the rate of the forward reaction equals that of the reverse reaction. (constant) At equilibrium, the ratio of products to reactants. (potential) The membrane potential for a given ion at which the voltage exactly balances the chemical diffusion gradient for that ion.

ERNST MAYR: Formulated the biological species concept.

ERYTHROCYTE: A red blood corpuscle.

ESOPHAGUS: An anterior part of the digestive tract; in mammals it leads from the pharynx to the stomach.

ESSENTIAL: 1) An amino or fatty acid which is required in the diet of an animal because it cannot be synthesized. 2) A chemical element required for a plant to grow from a seed and complete the life cycle.

ESTIVATION: A physiological state characterized by slow metabolism and inactivity, which permits survival during long periods of elevated temperature and diminished water supplies.

ESTRADIOL: 1,3,5(10)-estratriene- 3,17 beta-diol C₁₈H₂₄O₂. This is the natural hormone - present in pure form in the urine of pregnant mares and in the ovaries of pigs.

ESTROGEN: Any of a group of vertebrate female sex hormones.

ESTROUS CYCLE: In female mammals, the higher primates excepted, a recurrent series of physiological and behavioral changes connected with reproduction.

ESTRUS: The limited period of heat or sexual receptivity that occurs around ovulation in female mammals having estrous cycles.

ESTUARY: That portion of a river that is close enough to the sea to be influenced by marine tides.

ETHYLENE: The only gaseous plant hormone, responsible for fruit ripening, growth inhibition, leaf abscission, and aging.

EUBACTERIA: The lineage of prokaryotes that includes the cyanobacteria and all other contemporary bacteria except archaeobacteria.

EUCHROMATIN: The more open, unraveled form of eukaryotic chromatin, which is available for transcription.

EUCOELOMATE: An animal whose body cavity is completely lined by mesoderm, the layers of which connect dorsally and ventrally to form mesenteries.

EUGLENA: Euglena are common protists, of the class Euglenoidea of the phylum Euglenophyta. Currently, over 1000 species of Euglena have been described. Marin et al. (2003) revised the genus so and including several species without chloroplasts, formerly classified as Astasia and Khawkinia. Euglena sometimes can be considered to have both plant and animal features. Euglena gracilis has a long hair-like thing that stretches from its body. You need a very powerful microscope to see it. This is called a flagellum, and the euglena uses it to swim. It also has a red eyespot. Euglena gracilis uses its eyespot to locate light. Without light, it cannot use its chloroplasts to make itself food.

EUKARYOTE: A life form comprised of one or more cells containing a nucleus and membrane - bound organelles. Included are members of the Kingdoms Protista, Fungi, Plantae and Animalia.

EUMETAZOA: Members of the subkingdom that includes all animals except sponges.

EUTROPHIC: A highly productive condition in aquatic environments which owes to excessive concentrations of nutrients which support the growth of primary producers.

EVAGINATED: Folded or protruding outward.

EVAPORATIVE COOLING: The property of a liquid whereby the surface becomes cooler during evaporation, owing to the loss of highly kinetic molecules to the gaseous state.

EVERSIBLE: Capable of being turned inside out.

EVOLUTION: A theory that all of the changes that have transformed life on earth from its earliest beginnings to the diversity that characterizes it today. As used in biology, the term evolution means descent with change. See Intelligent Design.

EXCITABLE CELLS: A cell, such as a neuron or a muscle cell that can use changes in its membrane potential to conduct signals.

EXCITATORY POSTSYNAPTIC POTENTIAL: An electrical change (depolarization) in the membrane of a postsynaptic neuron caused by the binding of an excitatory neurotransmitter from a presynaptic cell to a postsynaptic receptor. This phenomenon facilitates generation of an action potential in the PSP.

EXCRETION: Release of materials which arise in the body due to metabolism (e.g., CO₂, NH₃, H₂O).

EXERGONIC: A phenomenon which involves the release of energy.

EXOCYTOSIS: A process by which a vesicle within a cell fuses with the plasma membrane and releases its contents to the outside.

EXON: A part of a primary transcript (and the corresponding part of a gene) that is ultimately either translated (in the case of mRNA) or utilized in a final product, such as tRNA.

EXOSKELETON: An external skeleton, characteristic of members of the phylum, Arthropoda.

EXOTHERMIC: A process or reaction that is accompanied by the creation of heat.

EXOTOXIN: A toxic protein secreted by a bacterial cell that produces specific symptoms even in the absence of the bacterium.

EXPONENTIAL: (population growth) The geometric increase of a population as it grows in an ideal, unlimited environment.

EXTRAEMBRYONIC MEMBRANES: Four membranes (yolk sac, amnion, chorion, allantois) that support the developing embryo in reptiles, birds, and mammals.

EXTRINSIC: External to, not a basic part of; as in extrinsic isolating mechanism.

F: The chemical symbol of Fluorine.

F PLASMID: The fertility factor in bacteria, a plasmid that confers the ability to form pili for conjugation and associated functions required for transfer of DNA from donor to recipient.

F1 GENERATION: The first filial or hybrid offspring in a genetic cross-fertilization.

F2 GENERATION: Offspring resulting from interbreeding of the hybrid F1 generation.

FACILITATED DIFFUSION: Passive movement through a membrane involving a specific carrier protein; does not proceed against a concentration gradient.

FACULTATIVE: An organism which exhibits the capability of changing from one habit or metabolic pathway to another, when conditions warrant. (anaerobe) An organism that makes ATP by aerobic respiration if oxygen is present but that switches to fermentation under anaerobic conditions.

FAT: A biological compound consisting of three fatty acids linked to one glycerol molecule.

FATE MAP: A means of tracing the fates of cells during embryonic development.

FATTY ACID: A long carbon chain carboxylic acid. Fatty acids vary in length and in the number and location of double bonds; three fatty acids linked to a glycerol molecule form fat.

FAUNA: The animals of a given area or period.

FEATURE DETECTOR: A circuit in the nervous system that responds to a specific type of feature, such as a vertically moving spot or a particular auditory time delay.

FECAL COLIFORM: A group of bacteria that may indicate the presence of human or animal fecal matter in water. Total coliform, fecal coliform, and *E. coli* are all indicators of drinking water quality. The total coliform group is a large collection of different kinds of bacteria. Fecal coliforms are types of total coliform that mostly exist in feces. *E. coli* is a sub-group of fecal coliform. When a water sample is sent to a lab, it is tested for total coliform. If total coliform is present, the sample will also be tested for either fecal coliform or *E. coli*, depending on the lab testing method.

FECES: Indigestible wastes discharged from the digestive tract.

FEEDBACK: The process by which a control mechanism is regulated through the very effects it brings about. Positive feedback is when the effect is amplified; negative feedback is when the effect tends toward restoration of the original condition. Feedback inhibition is a method of metabolic control in which the end-product of a metabolic pathway acts as an inhibitor of an enzyme within that pathway.

FERMENTATION: Anaerobic production of alcohol, lactic acid or similar compounds from carbohydrate resulting from glycolysis.

FERRIC CHLORIDE: An iron salt commonly used as a coagulant. Chemical formula is FeCl_3 .

FIBRIN: The activated form of the blood: clotting protein fibrinogen, which aggregates into threads that form the fabric of the clot.

FIBROBLAST: A type of cell in loose connective tissue that secretes the protein ingredients of the extracellular fibers.

FIBRONECTINS: A family of extracellular glycoproteins that helps embryonic cells adhere to their substrate as they migrate.

FILTER: A device utilizing a granular material, woven cloth or other medium to remove pollutants from water, wastewater or air.

FILTER AID: A polymer or other material added to improve the effectiveness of the filtration process.

FILTER CAKE: The layer of solids that is retained on the surface of a filter.

FILTER CLOGGING: An inability to meet demand may occur when filters are clogging.

FILTER PRESS: A dewatering device where sludge is pumped onto a filtering medium and water is forced out of the sludge, resulting in a "cake".

FILTRATE: Liquid remaining after removal of solids with filtration.

FILTRATION RATE: A measurement of the volume of water applied to a filter per unit of surface area in a given period of time.

FITNESS: The extent to which an individual passes on its genes to the next generation. Relative fitness is the number of offspring of an individual compared to the mean.

FIXATION: 1) Conversion of a substance into a biologically more usable form, for example, CO_2 fixation during photosynthesis and N_2 fixation. 2) Process of treating living tissue for microscopic examination.

FIXED ACTION PATTERN (FAP): A highly: stereotyped behavior that is innate and must be carried to completion once initiated.

FLACCID: Limp; walled cells are flaccid in isotonic surroundings, where there is no tendency for water to enter.

FLAGELLIN: The protein from which prokaryotic flagella are constructed.

FLAGELLUM: A long whip-like appendage that propels cells during locomotion in liquid solutions. The prokaryote flagellum is comprised of a protein, flagellin. The eukaryote flagellum is longer than a cilium, but as a similar internal structure of microtubules in a "9 + 2" arrangement.

FLAME CELL: A flagellated cell associated with the simplest tubular excretory system, present in flatworms: it acts to directly regulate the contents of the extracellular fluid.

FLOCCULATION: The process of bringing together destabilized or coagulated particles to form larger masses that can be settled and/or filtered out of the water being treated. Conventional coagulation–flocculation–sedimentation practices are essential pretreatments for many water purification systems—especially filtration treatments. These processes agglomerate suspended solids together into larger bodies so that physical filtration processes can more easily remove them. Particulate removal by these methods makes later filtering processes far more effective. The process is often followed by gravity separation (sedimentation or flotation) and is always followed by filtration. A chemical coagulant, such as iron salts, aluminum salts, or polymers, is added to source water to facilitate bonding among particulates. Coagulants work by creating a chemical reaction and eliminating the negative charges that cause particles to repel each other. The coagulant-source water mixture is then slowly stirred in a process known as flocculation. This water churning induces particles to collide and clump together into larger and more easily removable clots, or “flocs.” The process requires chemical knowledge of source water characteristics to ensure that an effective coagulant mix is employed. Improper coagulants make these treatment methods ineffective. The ultimate effectiveness of coagulation/flocculation is also determined by the efficiency of the filtering process with which it is paired.

FLOCCULANTS: Flocculants, or flocculating agents, are chemicals that promote flocculation by causing colloids and other suspended particles in liquids to aggregate, forming a floc. Flocculants are used in water treatment processes to improve the sedimentation or filterability of small particles. For example, a flocculant may be used in swimming pool or drinking water filtration to aid removal of microscopic particles which would otherwise cause the water to be cloudy and which would be difficult or impossible to remove by filtration alone. Many flocculants are multivalent cations such as aluminum, iron, calcium or magnesium[3]. These positively charged molecules interact with negatively charged particles and molecules to reduce the barriers to aggregation. In addition, many of these chemicals, under appropriate pH and other conditions such as temperature and salinity, react with water to form insoluble hydroxides which, upon precipitating, link together to form long chains or meshes, physically trapping small particles into the larger floc. Long-chain polymer flocculants, such as modified polyacrylamides, are manufactured and sold by the flocculant producing business. These can be supplied in dry or liquid form for use in the flocculation process. The most common liquid polyacrylamide is supplied as an emulsion with 10-40 % actives and the rest is a carrier fluid, surfactants and latex. Emulsion polymers require activation to invert the emulsion and allow the electrolyte groups to be exposed.

The following chemicals are used as flocculants:

- * alum
- * aluminum chlorohydrate
- * aluminum sulfate
- * calcium oxide
- * iron(III) chloride
- * iron(II) sulfate
- * polyacrylamide
- * sodium aluminate
- * sodium silicate

FLOC SHEARING: Likely to happen to large floc particles when they reach the flocculation process.

FLOCCULATION BASIN: A compartmentalized basin with a reduction of speed in each compartment. This set-up or basin will give the best overall results.

FLOOD RIM: The point of an object where the water would run over the edge of something and begin to cause a flood.

FLORA: The plants of a given area or period.

FLOW CYTOMETER: A particle-sorting instrument capable of counting protozoa.

FLOW MUST BE MEASURED: A recorder that measures flow is most likely to be located in a central location.

FLUID FEEDER: An animal that lives by sucking nutrient-rich fluids from another living organism.

FLUID MOSAIC MODEL: The currently accepted model of cell membrane structure, which envisions the membrane as a mosaic of individually inserted protein molecules drifting laterally in a fluid bilayer of phospholipids.

FLUX: The term flux describes the rate of water flow through a semipermeable membrane. When the water flux decreases through a semipermeable membrane, it means that the mineral concentration of the water is increasing.

FLY ASH: The noncombustible particles in flue gas. Often used as a body feed or solidification chemical.

FOLLICLE STIMULATING HORMONE (FSH): A gonadotropic hormone of the anterior pituitary that stimulates growth of follicles in the ovaries of females and function of the seminiferous tubules in males.

FOLLICLE: A jacket of cells around an egg cell in an ovary.

FOOD CHAIN: Sequence of organisms, including producers, consumers, and decomposers, through which energy and materials may move in a community.

FOOD WEB: The elaborate, interconnected feeding relationships in an ecosystem.

FOOT CANDLE: Unit of illumination; the illumination of a surface produced by one standard candle at a distance of one foot.

FORMULA: A precise representation of the structure of a molecule or ion, showing the proportion of atoms which comprise the material.

FOUNDER EFFECT: The difference between the gene pool of a population as a whole and that of a newly isolated population of the same species.

FRACTIONATION: An experimental technique which involves separation of parts of living tissue from one another using centrifugation.

FRAGMENTATION: A mechanism of asexual reproduction in which the parent plant or animal separates into parts that reform whole organisms.

FRAMESHIFT MUTATION: A mutation occurring when the number of nucleotides inserted or deleted is not a multiple of 3, thus resulting in improper grouping into codons.

FREE CHLORINE: In disinfection, chlorine is used in the form of free chlorine or as hypochlorite ion.

FREE CHLORINE RESIDUAL: Regardless of whether pre-chlorination is practiced or not, a free chlorine residual of at least 10 mg/L should be maintained in the clear well or distribution reservoir immediately downstream from the point of post-chlorination. The reason for chlorinating past the breakpoint is to provide protection in case of backflow.

FREE ENERGY OF ACTIVATION: See Activation energy.

FREE ENERGY: Usable energy in a chemical system; energy available for producing change.

FREE OIL: Non-emulsified oil that separates from water, in a given period of time.

FREQUENCY DEPENDENT SELECTION: A decline in the reproductive success of a morph resulting from the morph's phenotype becoming too common in a population; a cause of balanced polymorphism in populations.

FUNCTIONAL GROUP: One of several groups of atoms commonly found in organic molecules. A functional group contributes somewhat predictable properties to the molecules which possess them.

FUNDAMENTAL NICHE: The total resources an organism is theoretically capable of utilizing.

G: (protein) A membrane protein that serves as an intermediary between hormone receptors and the enzyme adenylate cyclase, which converts ATP to cAMP in the second messenger system in non-steroid hormone action. Depending on the system, G proteins either increase or decrease cAMP production.

G1 PHASE: The first growth phase of the cell cycle, consisting of the portion of interphase before DNA synthesis is initiated.

G2 PHASE: The second growth phase of the cell cycle, consisting of the portion of interphase after DNA synthesis but before mitosis.

GAIA HYPOTHESIS: An idea, first formulated by James E. Lovelock in 1979, which suggests that the biosphere of the earth exists as a "superorganism" which exhibits homeostatic self-regulation of the environment-biota global system.

GAMETANGIUM: The reproductive organ of bryophytes, consisting of the male antheridium and female archegonium; a multi-chambered jacket of sterile cells in which gametes are formed.

GAMETE: A sexual reproductive cell that must usually fuse with another such cell before development begins; an egg or sperm.

GAMETOPHYTE: A haploid plant that can produce gametes.

GANGLION: A structure containing a group of cell bodies of neurons.

GAP JUNCTION: A narrow gap between plasma membranes of two animal cells, spanned by protein channels. They allow chemical substances or electrical signals to pass from cell to cell.

GASTRULA: A two-layered, later three-layered, animal embryonic stage.

GASTRULATION: The process by which a blastula develops into a gastrula, usually by an involution of cells.

GATED ION CHANNEL: A membrane channel that can open or close in response to a signal, generally a change in the electrostatic gradient or the binding of a hormone, transmitter, or other molecular signal.

GEL ELECTROPHORESIS: In general, electrophoresis is a laboratory technique used to separate macromolecules on the basis of electric charge and size; the technique involves application of an electric field to a population of macromolecules which disperse according to their electric mobilities. In gel electrophoresis, the porous medium through which the macromolecules move is a gel.

GEL: Colloid in which the suspended particles form a relatively orderly arrangement.

GENE: The hereditary determinant of a specified characteristic of an individual; specific sequences of nucleotides in DNA.

GENE AMPLIFICATION: Any of the strategies that give rise to multiple copies of certain genes, thus facilitating the rapid synthesis of a product (such as rRNA for ribosomes) for which the demand is great.

GENE CLONING: Formation by a bacterium, carrying foreign genes in a recombinant plasmid, of a clone of identical cells containing the replicated foreign genes.

GENE DELIVERY: This is a general term for the introduction of new genetic elements into the genomes of living cells. The delivery problem is essentially conditioned by the fact that the new genetic elements are usually large, and by the presence of the outer cell membrane and the nuclear membrane acting as barriers to incorporation of the new DNA into the genome already present in the nucleus. Viruses possess various natural biochemical methods for achieving gene delivery; artificial gene delivery is one of the essential problems of "genetic engineering". The most important barrier is apparently the outer cell membrane, which is essentially a lipid barrier, and introduction of any large complex into the cell requires a fusion of one kind or another with this membrane. Liposomes, which consist of lipid membranes themselves, and which can fuse with outer cell membranes, are thus potential vehicles for delivery of many substances, including DNA.

GENE FLOW: The movement of genes from one part of a population to another, or from one population to another, via gametes.

GENE POOL: The sum total of all the genes of all the individuals in a population.

GENE REGULATION: Any of the strategies by which the rate of expression of a gene can be regulated, as by controlling the rate of transcription.

GENETIC DRIFT: Change in the gene pool as a result of chance and not as a result of selection, mutation, or migration.

GENETIC RECOMBINATION: The general term for the production of offspring that combine traits of the two parents.

GENETICS: The science of heredity; the study of heritable information.

GENOME: The cell's total complement of DNA.

GENOMIC EQUIVALENCE: The presence of all of an organism's genes in all of its cells.

GENOMIC IMPRINTING: The parental effect on gene expression. Identical alleles may have different effects on offspring depending on whether they arrive in the zygote via the ovum or via the sperm.

GENOMIC LIBRARY: A set of thousands of DNA segments from a genome, each carried by a plasmid or phage.

GENOTYPE: The particular combination of genes present in the cells of an individual.

GENUS: A taxonomic category above the species level, designated by the first word of a species' binomial Latin name.

GIARDIA LAMBLIA: *Giardia lamblia* (synonymous with *Lamblia intestinalis* and *Giardia duodenalis*) is a flagellated protozoan parasite that colonizes and reproduces in the small intestine, causing giardiasis. The giardia parasite attaches to the epithelium by a ventral adhesive disc, and reproduces via binary fission. Giardiasis does not spread via the bloodstream, nor does it spread to other parts of the gastro-intestinal tract, but remains confined to the lumen of the small intestine. Giardia trophozoites absorb their nutrients from the lumen of the small intestine, and are anaerobes.

GIARDIASIS, HEPATITIS OR TYHOID: Diseases that may be transmitted through the contamination of a water supply, but not AIDS.

GIS – GRAPHIC INFORMATION SYSTEM: Detailed information about the physical locations of structures such as pipes, valves, and manholes within geographic areas with the use of satellites.

GLIAL CELL: A non-conducting cell of the nervous system that provides support, insulation, and protection for the neurons.

GLIDING: Rod-shaped, gram-negative, mostly aerobic; glide on secreted slimy substances; form colonies, frequently with complex fruiting structures.

GLOMERULUS: A capillary bed within Bowman's capsule of the nephron; the site of ultrafiltration.

GLUCOSE: A six carbon sugar which plays a central role in cellular metabolism.

GLYCOCALYX: The layer of protein and carbohydrates just outside the plasma membrane of an animal cell; in general, the proteins are anchored in the membrane, and the carbohydrates are bound to the proteins.

GLYCOGEN: A long, branched polymer of glucose subunits that is stored in the muscles and liver of animals and is metabolized as a source of energy.

GLYCOLYSIS: A metabolic pathway which occurs in the cytoplasm of cells and during which glucose is oxidized anaerobically to form pyruvic acid.

GLYCOPROTEIN: A protein with covalently linked sugar residues. The sugars may be bound to OH side chains of the polypeptide (O: linked) or the amide nitrogen of asparagine side chains (N: linked).

GLYCOSIDIC: A type of bond which links monosaccharide subunits together in di- or polysaccharides.

GLYOXYSOME: A type of microbody found in plants, in which stored lipids are converted to carbohydrates.

GOLGI APPARATUS: A system of concentrically folded membranes found in the cytoplasm of eukaryotic cells. Plays a role in the production and release of secretory materials such as the digestive enzymes manufactured in the pancreas.

GONADOTROPIN: Refers to a member of a group of hormones capable of promoting growth and function of the gonads. Includes hormones such as follicle stimulating hormone (FSH) and luteinizing hormone (LH) which are stimulatory to the gonads.

GOOD CONTACT TIME, pH and LOW TURBIDITY: These are factors that are important in providing good disinfection when using chlorine.

GPM: Gallons per minute.

GRAB SAMPLE: A sample which is taken from a water or wastestream on a one-time basis with no regard to the flow of the water or wastestream and without consideration of time. A single grab sample should be taken over a period of time not to exceed 15 minutes.

GRAB SAMPLE: A single water or wastewater sample taken at a time and place representative of total discharge.

GRADED POTENTIAL: A local voltage change in a neuron membrane induced by stimulation of a neuron, with strength proportional to the strength of the stimulus and lasting about a millisecond.

GRANUM: A stack-like grouping of photosynthetic membranes in a chloroplast

GRAVITY BELT THICKENER: A sludge dewatering device utilizing a filter belt to promote gravity drainage of water. Usually precedes additional dewatering treatment.

GRAVITY FILTER: A filter that operates at atmospheric pressure.

GRAVITY THICKENING: A sedimentation basin designed to operate at high solids loading rates.

GRAVITROPISM: A response of a plant or animal in response to gravity.

GREENHOUS EFFECT: The warming of the Earth due to atmospheric accumulation of carbon dioxide which absorbs infrared radiation and slows its escape from the irradiated Earth.

GREGOR MENDEL: The first to make quantitative observations of the patterns of inheritance and proposing plausible explanations for them.

GROWTH FACTOR: A protein that must be present in a cell's environment for its normal growth and development.

GT: Represents (Detention time) x (mixing intensity) in flocculation.

GUARD CELL: A specialized epidermal cell that regulates the size of stoma of a leaf.

GYMNOSPERM: A vascular plant that bears naked seeds not enclosed in any specialized chambers.

H₂SO₄: The molecular formula of Sulfuric acid.

HABIT: In biology, the characteristic form or mode of growth of an organism.

HABITAT: The kind of place where a given organism normally lives.

HABITUATION: The process that results in a long-lasting decline in the receptiveness of interneurons to the input from sensory neurons or other interneurons (sensitization, adaptation).

HALF: The average amount of time it takes for one-half of a specified quantity of a substance to decay or disappear.

HALIDES: A halide is a binary compound, of which one part is a halogen atom and the other part is an element or radical that is less electronegative than the halogen, to make a fluoride, chloride, bromide, iodide, or astatide compound. Many salts are halides. All Group 1 metals form halides with the halogens and they are white solids. A halide ion is a halogen atom bearing a negative charge. The halide anions are fluoride (F), chloride (Cl), bromide (Br), iodide (I) and astatide (At). Such ions are present in all ionic halide salts.

HALOACETIC ACIDS: Haloacetic acids are carboxylic acids in which a halogen atom takes the place of a hydrogen atom in acetic acid. Thus, in a monohaloacetic acid, a single halogen would replace a hydrogen atom. For example, chloroacetic acid would have the structural formula $\text{CH}_2\text{ClCO}_2\text{H}$. In the same manner, in dichloroacetic acid two chlorine atoms would take the place of two hydrogen atoms ($\text{CHCl}_2\text{CO}_2\text{H}$).

HAPLOID: The condition of having only one kind of a given type of chromosome.

HARD WATER: Hard water causes a buildup of scale in household hot water heaters. Hard water is a type of water that has high mineral content (in contrast with soft water). Hard water primarily consists of calcium (Ca^{2+}), and magnesium (Mg^{2+}) metal cations, and sometimes other dissolved compounds such as bicarbonates and sulfates. Calcium usually enters the water as either calcium carbonate (CaCO_3), in the form of limestone and chalk, or calcium sulfate (CaSO_4), in the form of other mineral deposits. The predominant source of magnesium is dolomite ($\text{CaMg}(\text{CO}_3)_2$). Hard water is generally not harmful. The simplest way to determine the hardness of water is the lather/froth test: soap or toothpaste, when agitated, lathers easily in soft water but not in hard water. More exact measurements of hardness can be obtained through a wet titration. The total water 'hardness' (including both Ca^{2+} and Mg^{2+} ions) is read as parts per million or weight/volume (mg/L) of calcium carbonate (CaCO_3) in the water. Although water hardness usually only measures the total concentrations of calcium and magnesium (the two most prevalent, divalent metal ions), iron, aluminum, and manganese may also be present at elevated levels in some geographical locations.

HARDNESS: A measure of the amount of calcium and magnesium salts in water. More calcium and magnesium lead to greater hardness. The term "hardness" comes from the fact that it is hard to get soap suds from soap or detergents in hard water. This happens because calcium and magnesium react strongly with negatively-charged chemicals like soap to form insoluble compounds.

HARDY-WEINBERG THEOREM: An axiom maintaining that the sexual shuffling of genes alone cannot alter the overall genetic makeup of a population.

HAUSTORIUM: In parasitic fungi, a nutrient-absorbing hyphal tip that penetrates the tissues of the host but remains outside the host cell membranes.

HAVERSIAN SYSTEM: One of many structural units of vertebrate bone, consisting of concentric layers of mineralized bone matrix surrounding lacunae, which contain osteocytes, and a central canal, which contains blood vessels and nerves.

HAZARDS OF POLYMERS: Slippery and difficult to clean-up are the most common hazards associated with the use of polymers in a water treatment plant.

HEAD: The measure of the pressure of water expressed in feet of height of water. 1 PSI = 2.31 feet of water or 1 foot of head equals about a half a pound of pressure or .433 PSI. There are various types of heads of water depending upon what is being measured. Static (water at rest) and Residual (water at flow conditions).

HEADWORKS: The facility at the "head" of the water source where water is first treated and routed into the distribution system.

HEALTH ADVISORY: An EPA document that provides guidance and information on contaminants that can affect human health and that may occur in drinking water, but which the EPA does not currently regulate in drinking water.

HEAT OF VAPORIZATION: The amount of energy absorbed by a substance when it changes state to a gas. Water absorbs approximately 580 calories per gram when it changes from liquid water to water vapor.

HEAT: The total amount of kinetic energy due to molecular motion in a body of matter. Heat is energy in its most random form.

HELPER T CELL: A type of T cell that is required by some B cells to help them make antibodies or that helps other T cells respond to antigens or secrete lymphokines or interleukins.

HEMAGGLUTININ: A surface antigen on influenza viruses which controls infectivity by associating with receptors on host erythrocytes or other cells.

HEMATOPOIESIS: The formation of blood.

HEMATOPOIETIC STEM CELLS: Cells found in the bone marrow of adult mammals which give rise to erythroid stem cells, lymphoid stem cells, and myeloid stem cells. Such cells give rise to erythrocytes and a variety of types of lymphocytes and leucocytes.

HEMOGLOBIN: An iron-containing respiratory pigment found in many organisms.

HEMOLymph: In invertebrates with open circulatory systems, the body fluid that bathes tissues.

HEMOPHILIA: A genetic disease resulting from an abnormal sex-linked recessive gene, characterized by excessive bleeding following injury.

HEPATIC: Pertaining to the liver.

HEREDITY: A biological phenomenon whereby characteristics are transmitted from one generation to another by virtue of chemicals (i.e. DNA) transferred during sexual or asexual reproduction.

HERPESVIRUS: A double stranded DNA virus with an enveloped, icosahedral capsid.

HERTZ: The term used to describe the frequency of cycles in an alternating current (AC) circuit. A unit of frequency equal to one cycle per second.

HETEROCHROMATIN: Non-transcribed eukaryotic chromatin that is so highly compacted that it is visible with a light microscope during interphase.

HETEROCHRONY: Evolutionary changes in the timing or rate of development.

HETEROCYST: A specialized cell that engages in nitrogen fixation on some filamentous cyanobacteria.

HETEROGAMY: The condition of producing gametes of two different types (contrast with isogamy).

HETEROMORPHIC: A condition in the life cycle of all modern plants in which the sporophyte and gametophyte generations differ in morphology.

HETEROSPOROUS: Referring to plants in which the sporophyte produces two kinds of spores that develop into unisexual gametophytes, either male or female.

HETEROTROPH: An organism dependent on external sources of organic compounds as a means of obtaining energy and/or materials. Such an organism requires carbon ("food") from its environment in an organic form. (synonym-organotroph).

HETEROTROPHIC PLATE COUNT: A test performed on drinking water to determine the total number of all types of bacteria in the water.

HETEROZYGOTE ADVANTAGE: A mechanism that preserves variation in eukaryotic gene pools by conferring greater reproductive success on heterozygotes over individuals homozygous for any one of the associated alleles.

HETEROZYGOUS: The condition whereby two different alleles of the gene are present within the same cell.

HF: The molecular formula of Hydrofluoric acid.

HIGH TURBIDITY CAUSING INCREASED CHLORINE DEMAND: May occur or be caused by the inadequate disinfection of water.

HISTAMINE: A substance released by injured cells that causes blood vessels to dilate during an inflammatory response.

HISTOLOGY: The study of tissues.

HISTONE: A type of protein characteristically associated with the chromosomes of eukaryotes.

HIV-1: Acute human immunodeficiency virus type 1 is the subtype of HIV (human immune deficiency virus) that causes most cases of AIDS in the Western Hemisphere, Europe, and Central, South, and East Africa. HIV is a retrovirus (subclass lentivirus), and retroviruses are single: stranded RNA viruses that have an enzyme called reverse transcriptase. With this enzyme the viral RNA is used as a template to produce viral DNA from cellular material. This DNA is then incorporated into the host cell's genome, where it codes for the synthesis of viral components. An HIV-1 infection should be distinguished from AIDS. Acquired immunodeficiency syndrome (AIDS) is a secondary immunodeficiency syndrome resulting from HIV infection and characterized by opportunistic infections, malignancies, neurologic dysfunction, and a variety of other syndromes.

HOLOBLASTIC: A type of cleavage in which there is complete division of the egg, as in eggs having little yolk (sea urchin) or a moderate amount of yolk (frog).

HOME RANGE: An area within which an animal tends to confine all or nearly all its activities for a long period of time.

HOMEBOX: Specific sequences of DNA that regulate patterns of differentiation during development of an organism.

HOMEOSTASIS: A phenomenon whereby a state or process (for example, within an organism) is regulated automatically despite the tendency for fluctuations to occur.

HOMEOTHEMIC: Capable of regulation of constancy with respect to temperature.

HOMEOTIC GENES: Genes that control the overall body plan of animals by controlling the developmental fate of groups of cells.

HOMEOTIC: (mutation) A mutation in genes regulated by positional information that results in the abnormal substitution of one type of body part in place of another.

HOMOLOGOUS CHROMOSOMES: Chromosomes bearing genes for the same characters.

HOMOLOGOUS STRUCTURES: Characters in different species which were inherited from a common ancestor and thus share a similar ontogenetic pattern.

HOMOLOGY: Similarity in characteristics resulting from a shared ancestry.

HOMOPLASY: The presence in several species of a trait not present in their most common ancestor. Can result from convergent evolution, reverse evolution, or parallel evolution.

HOMOSPOROUS: Referring to plants in which a single type of spore develops into a bisexual gametophyte having both male and female sex organs.

HOMOZYGOUS: Having two copies of the same allele of a given gene.

HORMONE: A control chemical secreted in one part of the body that affects other parts of the body.

HOST RANGE: The limited number of host species, tissues, or cells that a parasite (including viruses and bacteria) can infect.

HUMORAL IMMUNITY: The type of immunity that fights bacteria and viruses in body fluids with antibodies that circulate in blood plasma and lymph, fluids formerly called humors.

HYBIRD VIGOR: Increased vitality (compared to that of either parent stock) in the hybrid offspring of two different, inbred parents.

HYBIRD: In evolutionary biology, a cross between two species. In genetics, a cross between two genetic types.

HYBIRDIZATION: The process whereby a hybrid results from interbreeding two species; 2) DNA hybridization is the comparison of whole genomes of two species by estimating the extent of hydrogen bonding that occurs between single-stranded DNA obtained from the two species.

HYBRIDOMA: A hybrid cell that produces monoclonal antibodies in culture, formed by the fusion of a myeloma cell with a normal antibody-producing lymphocyte.

HYDRATED LIME: The calcium hydroxide product that results from mixing quicklime with water. Chemical formula is CaOH_2 .

HYDRATION SHELL: A "covering" of water molecules which surrounds polar or charged substances in aqueous solutions. The association is due to the charged regions of the polar water molecules themselves.

HYDRIDES: Hydride is the name given to the negative ion of hydrogen, H. Although this ion does not exist except in extraordinary conditions, the term hydride is widely applied to describe compounds of hydrogen with other elements, particularly those of groups 1–16. The variety of compounds formed by hydrogen is vast, arguably greater than that of any other element. Various metal hydrides are currently being studied for use as a means of hydrogen storage in fuel cell-powered electric cars and batteries. They also have important uses in organic chemistry as powerful reducing agents, and many promising uses in hydrogen economy.

Every element of the periodic table (except some noble gases) forms one or more hydrides. These compounds may be classified into three main types by the predominant nature of their bonding:

- * Saline hydrides, which have significant ionic character,
- * Covalent hydrides, which include the hydrocarbons and many other compounds, and
- * Interstitial hydrides, which may be described as having metallic bonding.

HYDROCARBON: Any compound made of only carbon and hydrogen.

HYDROCHLORIC AND HYPOCHLOROUS ACIDS: The compounds that are formed in water when chlorine gas is introduced.

HYDROFLUOSILIC ACID: (H_2SiF_6) a clear, fuming corrosive liquid with a pH ranging from 1 to 1.5. Used in water treatment to fluoridate drinking water.

HYDROGEN BOND: A type of bond formed when the partially positive hydrogen atom of a polar covalent bond in one molecule is attracted to the partially negative atom of a polar covalent bond in another.

HYDROGEN SULFIDE OR CHLORINE GAS: These chemicals can cause olfactory fatigue.

HYDROPHOBIC: Does not mix readily with water.

HYDROGEN ION: A single proton with a charge of +1. The dissociation of a water molecule (H_2O) leads to the generation of a hydroxide ion (OH^-) and a hydrogen ion (H^+).

HYDROGEN SULFIDE: A toxic gas formed by the anaerobic decomposition of organic matter. Chemical formula is H_2S .

HYDROLYSIS: The chemical reaction that breaks a covalent bond through the addition of hydrogen (from a water molecule) to the atom forming one side of the original bond, and a hydroxyl group to the atom on the other side.

HYDROPHILIC: Having an affinity for water.

HYDROPHOBIC INTERACTION: A type of weak chemical bond formed when molecules that do not mix with water coalesce to exclude the water.

HYDROPHOBIC: The physicochemical property whereby a substance or region of a molecule resists association with water molecules.

HYDROSTATIC: Pertaining to the pressure and equilibrium of fluids. A hydrostatic skeleton is a skeletal system composed of fluid held under pressure in a closed body compartment; the main skeleton of most cnidarians, flatworms, nematodes, and annelids.

HYDROXYL GROUP: A functional group consisting of a hydrogen atom joined to an oxygen atom by a polar covalent bond. Molecules possessing this group are soluble in water and are called alcohols.

HYDROXYL ION: The OH⁻ ion.

HYPEROSMOTIC: A solution with a greater solute concentration than another, a hypoosmotic solution. If the two solutions are separated from one another by a membrane permeable to water, water would tend to move from the hypo- to the hyperosmotic side.

HYPERPOLARIZATION: An electrical state whereby the inside of the cell is made more negative relative to the outside than was the case at resting potential. A neuron membrane is hyperpolarized if the voltage is increased from the resting potential of about -70 mV, reducing the chance that a nerve impulse will be transmitted.

HYPERTROPHY: Abnormal enlargement, excessive growth.

HYPHA: A fungal filament.

HYPOCHLORITE AND ORGANIC MATERIALS: Heat and possibly fire may occur when hypochlorite is brought into contact with an organic material.

HYPOCOTYL: The portion of the axis of a plant embryo below the point of attachment of the cotyledons; forms the base of the shoot and the root.

HYPOOSMOTIC SOLUTION: A solution with a lesser solute concentration than another, a hyperosmotic solution. If the two solutions are separated from one another by a membrane permeable to water, water would tend to move from the hypo- to the hyperosmotic side.

HYPOTHESIS: A formal statement of supposition offered to explain observations. Note that a hypothesis is only useful if it can be tested. Even if correct, it is not scientifically useful if untestable.

HYPOTHETICO-DEDUCTIVE: A method used to test hypotheses. If deductions formulated from the hypothesis are tested and proven false, the hypothesis is rejected.

IMAGINAL DISK: An island of undifferentiated cells in an insect larva, which are committed (determined) to form a particular organ during metamorphosis to the adult.

IMBIBITION: The soaking of water into a porous material that is hydrophilic.

IMMUNE RESPONSE: 1) A primary immune response is the initial response to an antigen, which appears after a lag of a few days. 2) A secondary immune response is the response elicited when the animal encounters the same antigen at a later time. The secondary response is normally more rapid, of greater magnitude and of longer duration than the primary response.

IMMUNOGLOBULINE: The class of proteins comprising the antibodies.

IMMUNOLOGICAL: 1) Immunological distance is the amount of difference between two proteins as measured by the strength of the antigen: antibody reaction between them. 2) Immunological tolerance is a mechanism by which an animal does not mount an immune response to the antigenic determinants of its own macromolecules.

IMMUNOMAGNETIC SEPARATION (IMS): A purification procedure that uses microscopic, magnetically responsive particles coated with an antibodies targeted to react with a specific pathogen in a fluid stream. Pathogens are selectively removed from other debris using a magnetic field.

IMPELLERS: The semi-open or closed props or blades of a turbine pump that when rotated generate the pumping force.

IMPERVIOUS: Not allowing, or allowing only with great difficulty, the movement of water.

IMPRINTING: A type of learned behavior with a significant innate component, acquired during a limited critical period.

IN SERIES: Several components being connected one to the other without a bypass, requiring each component to work dependent on the one before it.

IN SITU: Treatment or disposal methods that do not require movement of contaminated material.

IN VITRO FERTILIZATION: Fertilization of ova in laboratory containers followed by artificial implantation of the early embryo in the mother's uterus.

INCINERATION: The process of reducing the volume of a material by burning and reducing to ash if possible.

INCLINED PLATE SEPARATOR: A series of parallel inclined plates that can be used to increase the efficiency of clarifiers and gravity thickeners.

INCOMPLETE DOMINANCE: A type of inheritance in which F1 hybrids have an appearance that is intermediate between the phenotypes of the parental varieties.

INDETERMINATE: 1) A type of cleavage exhibited during the embryonic development in deuterostomes, in which each cell produced by early cleavage divisions retains the capacity to develop into a complete embryo; 2) A type of growth exhibited by plants: they continue to grow as long as they live, because they always retain meristematic cells capable of undergoing mitosis.

INDIRECT REUSE: The beneficial use of reclaimed water into natural surface waters or groundwater.

INDUCED FIT: The change in shape of the active site of an enzyme so that it binds more snugly to the substrate, induced by entry of the substrate.

INDUCTION: 1) The ability of one group of embryonic cells to influence the development of another. 2) A method in logic which proceeds from the specific to general and develops a general statement which explains all of the observations. Commonly used to formulate scientific hypotheses.

INDUSTRIAL MELANISM: Melanism which has resulted from blackening of environmental surfaces (tree bark, etc.) by industrial pollution. This favors survival of melanic forms such as moths which rest on tree bark and are less likely to be seen by predators.

INDUSTRIAL WASTEWATER: Liquid wastes resulting from industrial processes.

INFECTIOUS: 1) An infectious disease is a disease caused by an infectious microbial or parasitic agent. 2) Infectious hepatitis is the former name for hepatitis A. 3) Infectious mononucleosis is an acute disease that affects many systems, caused by the Epstein: Barr virus.

INFECTIOUS PATHOGENS/MICROBES/GERMS: are considered disease-producing bacteria, viruses and other microorganisms.

INFLAMMATORY RESPONSE: A line of defense triggered by penetration of the skin or mucous membranes, in which small blood vessels in the vicinity of an injury dilate and become leakier, enhancing infiltration of leukocytes; may also be widespread in the body.

INFLUENT: Water or wastewater flowing into a basin or treatment plant.

INGESTION: A heterotrophic mode of nutrition in which other organisms or detritus are eaten whole or in pieces.

INHIBITORY POSTSYNAPTIC POTENTIAL: An electrical charge (hyperpolarization) in the membrane of a postsynaptic neuron caused by the binding of an inhibitory neurotransmitter from a presynaptic cell to a postsynaptic receptor.

INITIAL PRECISION AND RECOVERY (IPR): Four aliquots of spiking suspension analyzed to establish the ability to generate acceptable precision and accuracy. An IPR is performed prior to the first time this method is used and any time the method or instrumentation is modified.

INNER CELL MASS: A cluster of cells in a mammalian blastocyst that protrudes into one end of the cavity and subsequently develops into the embryo proper and some of the extraembryonic membranes.

INORGANIC COMPOUND: Compounds that contain no carbon or contain only carbon bound to elements other than hydrogen.

INORGANIC CONTAMINANTS: Mineral-based compounds such as metals, nitrates, and asbestos. These contaminants are naturally-occurring in some water, but can also get into water through farming, chemical manufacturing, and other human activities. EPA has set legal limits on 15 inorganic contaminants.

INORGANIC IONS: Present in all waters. Inorganic ions are essential for human health in small quantities, but in larger quantities they can cause unpleasant taste and odor or even illness. Most community water systems will commonly test for the concentrations of seven inorganic ions: nitrate, nitrite, fluoride, phosphate, sulfate, chloride, and bromide. Nitrate and nitrite can cause an illness in infants called methemoglobinemia. Fluoride is actually added to the drinking water in some public water systems to promote dental health. Phosphate, sulfate, chloride, and bromide have little direct effect on health, but high concentrations of inorganic ions can give water a salty or briny taste.

INSOLUBLE COMPOUNDS: are types of compounds cannot be dissolved. When iron or manganese reacts with dissolved oxygen (**DO**) insoluble compound are formed.

INTAKE FACILITIES: One of the more important considerations in the construction of intake facilities is the ease of operation and maintenance over the expected lifetime of the facility. Every intake structure must be constructed with consideration for operator safety and for cathodic protection.

INOSITOL TRIPHOSPHATE: The second messenger, which functions as an intermediate between certain non-steroid hormones and the third messenger, a rise in cytoplasmic Ca^{++} concentration.

INSERTION: A mutation involving the addition of one or more nucleotide pairs to a gene.

INSIGHT LEARNING: The ability of an animal to perform a correct or appropriate behavior on the first attempt in a situation with which it has had no prior experience.

INSULIN: The vertebrate hormone that lowers blood sugar levels by promoting the uptake of glucose by most body cells and promoting the synthesis and storage of glycogen in the liver; also stimulates protein and fat synthesis; secreted by endocrine cells of the pancreas called islets of Langerhans.

INTEGRAL PROTEIN: A protein of biological membranes that penetrates into or spans the membrane.

INTERBREED: To breed with another kind or species; hybridize.

INTERFERON: A chemical messenger of the immune system, produced by virus: infected cells and capable of helping other cells resist the virus.

INTERLEUKIN: 1: A chemical regulator (cytokine) secreted by macrophages that have ingested a pathogen or foreign molecule and have bound with a helper T cell; stimulates T cells to grow and divide and elevates body temperature. Interleukin: 2, secreted by activated T cells, stimulates helper T cells to proliferate more rapidly.

INTERMEDIATE FILAMENT: A component of the cytoskeleton that includes all filaments intermediate in size between microtubules and microfilaments.

INTERNEURON: An association neuron; a nerve cell within the central nervous system that forms synapses with sensory and motor neurons and integrates sensory input and motor output.

INTERNODE: The segment of a plant stem between the points where leaves are attached.

INTERSTITIAL CELLS: Cells scattered among the seminiferous tubules of the vertebrate testis that secrete testosterone and other androgens, the male sex hormones.

INTERSTITIAL FLUID: The internal environment of vertebrates consisting of the fluid filling the spaces between cells.

INTERTIDAL ZONE: The shallow zone of the ocean where land meets water.

INTRINSIC RATE OF INCREASE: The difference between number of births and number of deaths, symbolized as r_{max} ; maximum population growth rate.

INTROGRESSION: Transplantation of genes between species resulting from fertile hybrids mating successfully with one of the parent species.

INTRON: The noncoding, intervening sequence of coding region (exon) in eukaryotic genes.

INVAGINATION: The buckling inward of a cell layer, caused by rearrangements of microfilaments and microtubules; an important phenomenon in embryonic development.

INVERSION: 1) An aberration in chromosome structure resulting from an error in meiosis or from mutagens; reattachment in a reverse orientation of a chromosomal fragment to the chromosome from which the fragment originated. 2) A phenomenon which occurs during early development of sponges at which time the external ciliated cells become inward-directed.

INVERTEBRATE: An animal without a backbone; invertebrates make up about 95% of animal species.

ION: A charged chemical formed when an atom or group of atoms has more or less electrons than protons (rather than an equal number).

ION EXCHANGE: An effective treatment process used to remove iron and manganese in a water supply. The hardness of the source water affects the amount of water an ion exchange softener may treat before the bed requires regeneration.

IONIC BOND: A chemical bond due to attraction between oppositely charged ions.

IRON: The elements iron and manganese are undesirable in water because they cause stains and promote the growth of iron bacteria.

IRON AND MANGANESE: In water they can usually be detected by observing the color of the inside walls of filters and the filter media. If the raw water is pre-chlorinated, there will be black stains on the walls below the water level and a black coating over the top portion of the sand filter bed. When significant levels of dissolved oxygen are present, iron and manganese exist in an oxidized state and normally precipitate into the reservoir bottom sediments. The presence of iron and manganese in water promote the growth of Iron bacteria. Only when a water sample has been acidified then you can perform the analysis beyond the 48 hour holding time. Iron and Manganese in water may be detected by observing the color of the of the filter media. Maintaining a free chlorine residual and regular flushing of water mains may control the growth of iron bacteria in a water distribution system.

IRRUPTION: A rapid increase in population density often followed by a mass emigration.

ISOGAMY: A condition in which male and female gametes are morphologically indistinguishable.

ISOMER: Molecules consisting of the same numbers and kinds of atoms, but differing in the way in which the atoms are combined.

ISOSMOTIC: Solutions of equal concentration with respect to osmotic pressure.

ISOTOPE: An atomic form of an element, containing a different number of neutrons than another isotope. Isotopes vary from one another with respect to atomic mass.

JUXTAGLOMERULAR APPARATUS (JGA): Specialized tissue located near the afferent arteriole that supplies blood to the kidney glomerulus; JGA raises blood pressure by producing renin, which activates angiotensin.

K- SELECTION: The concept that life history of the population is centered upon producing relatively few offspring that have a good chance of survival.

KARYOGAMY: The fusion of nuclei of two cells, as part of syngamy.

KARYOTYPE: A method of classifying the chromosomes of a cell in relation to number, size and type.

KEYSTONE PREDATOR: A species that maintains species richness in a community through predation of the best competitors in the community, thereby maintaining populations of less competitive species.

KILOCALORIE: A thousand calories; the amount of heat energy required to raise the temperature of 1 kilogram of water by primary C.

KILL = C X T: Where other factors are constant, the disinfecting action may be represented by: Kill=C x T.

KIN SELECTION: A phenomenon of inclusive fitness, used to explain altruistic behavior between related individuals.

KINESIS: A change in activity rate in response to a stimulus.

KINETIC ENERGY: The ability of an object to do work by virtue of its motion. The energy terms that are used to describe the operation of a pump are pressure and head. The energy of motion. Moving matter does work by transferring some of its kinetic energy to other matter.

KINETOCHORE: A specialized region on the centromere that links each sister chromatid to the mitotic spindle.

KINGDOM: A taxonomic category, the second broadest after domain.

KREBS CYCLE: A chemical cycle involving eight steps that completes the metabolic breakdown of glucose molecules to carbon dioxide; occurs within the mitochondrion; the second major stage in cellular respiration. Also called citric acid cycle or tricarboxylic acid (TCA) cycle.

LABORATORY BLANK: See Method blank

LABORATORY CONTROL SAMPLE (LCS): See Ongoing precision and recovery (OPR) standard

LACTEAL: A tiny lymph vessel extending into the core of the intestinal villus and serving as the destination for absorbed chylomicrons.

LACTIC ACID: Gram-positive, anaerobic; produce lactic acid through fermentation; include Lactobacillus, essential in dairy product formation, and Streptococcus, common in humans.

LAGGING STRAND: A discontinuously synthesized DNA strand that elongates in a direction away from the replication fork.

LAMARCK: Proposed, in the early 1800s, that evolutionary change may occur via the inheritance of acquired characteristics. This idea, which has since been discredited, holds that the changes in characteristics which occur during an individual's life can be passed on to its offspring.

LAND APPLICATION: The disposal of wastewater or municipal solids onto land under controlled conditions.

LAND DISPOSAL: Application of municipal wastewater solids to the soil without production of usable agricultural products.

LANDFILL: A land disposal site that employs an engineering method of solid waste disposal to minimize environmental hazards and protect the quality of surface and subsurface waters.

LANGELIER INDEX: A measurement of Corrosivity. The water is becoming corrosive in the distribution system causing rusty water if the Langelier index indicates that the pH has decreased from the equilibrium point. Mathematically derived factor obtained from the values of calcium hardness, total alkalinity, and pH at a given temperature. A Langelier index of zero indicates perfect water balance (i.e., neither corroding nor scaling). The Langelier Saturation Index (sometimes Langelier Stability Index) is a calculated number used to predict the calcium carbonate stability of water. It indicates whether the water will precipitate, dissolve, or be in equilibrium with calcium carbonate. Langelier developed a method for predicting the pH at which water is saturated in calcium carbonate (called pHs). The LSI is expressed as the difference between the actual system pH and the saturation pH.

$LSI = pH - pH_s$

If the actual pH of the water is below the calculated saturation pH, the LSI is negative and the water has a very limited scaling potential. If the actual pH exceeds pHs, the LSI is positive, and being supersaturated with $CaCO_3$, the water has a tendency to form scale. At increasing positive index values, the scaling potential increases.

Langelier saturation index is defined as:

$LSI = pH \text{ (measured)} - pH_s$

* For $LSI > 0$, water is super saturated and tends to precipitate a scale layer of $CaCO_3$

* For $LSI = 0$, water is saturated (in equilibrium) with $CaCO_3$. A scale layer of $CaCO_3$ is neither precipitated nor dissolved

* For $LSI < 0$, water is under saturated and tends to dissolve solid $CaCO_3$

In practice, water with an LSI between -0.5 and +0.5 will not display enhanced mineral dissolving or scale forming properties. Water with an LSI below -0.5 tends to exhibit noticeably increased dissolving abilities while water with an LSI above +0.5 tends to exhibit noticeably increased scale forming properties.

It is also worth noting that the LSI is temperature sensitive. The LSI becomes more positive as the water temperature increases. This has particular implications in situations where well water is used. The temperature of the water when it first exits the well is often significantly lower than the temperature inside the building served by the well or at the laboratory where the LSI measurement is made.

LARVA (pl. larvae): A free-living, sexually immature form in some animal life cycles that may differ from the adult in morphology, nutrition, and habitat.

LATERAL LINE SYSTEM: A mechanoreceptor system consisting of a series of pores and receptor units (neuromasts) along the sides of the body of fishes and aquatic amphibians; detects water movements made by an animal itself and by other moving objects.

LATERAL MERISTEMS: The vascular and cork cambia, cylinders of dividing cells that run most of the length of stems and roots and are responsible for secondary growth.

LAW OF INDEPENDENT ASSORTMENT: Mendel's second law, stating that each allele pair segregates independently during gamete formation; applies when genes for two traits are located on different pairs of homologous chromosomes.

LAW OF SEGREGATION: Mendel's first law, stating that allele pairs separate during gamete formation, and then randomly re-form pairs during the fusion of gametes at fertilization.

LEACHATE: Fluid that trickles through solid materials or wastes and contains suspended or dissolved materials or products of the solids.

LEACHING: A chemical reaction between water and metals that allows for removal of soluble materials.

LEADING STRAND: The new continuously complementary DNA strand synthesized along the template strand in the 5' → 3' direction.

LEUKOCYTE: A white blood cell; typically functions in immunity, such as phagocytosis or antibody production.

LEVELS OF ORGANIZATION: A basic concept in biology is that organization is based on a hierarchy of structural levels, with each level building on the levels below it.

LICHEN: An organism formed by the symbiotic association between a fungus and a photosynthetic alga.

LIFE: (table) A table of data summarizing mortality in a population.

LIGAMENT: A type of fibrous connective tissue that joins bones together at joints.

LIGAND: A ligand is a molecule that binds specifically to a receptor site of another molecule. A ligase is an enzyme which catalyzes such a reaction. For example, a DNA ligase is an enzyme which catalyzes the covalent bonding of the 3' end of a new DNA fragment to the 5' end of a growing chain.

LIGASE: Ligases are enzymes that catalyze the "stitching together" of polymer fragments. DNA ligase, for example, catalyzes phosphodiester bond formation between two DNA fragments, and this enzyme is involved in normal DNA replication, repair of damaged chromosomes, and various in vitro techniques in genetic engineering that involve linking DNA fragments.

LIGNIN: A hard material embedded in the cellulose matrix of vascular plant cell walls that functions as an important adaptation for support in terrestrial species.

LIBIC SYSTEM: A group of nuclei (clusters of nerve cell bodies) in the lower part of the mammalian forebrain that interact with the cerebral cortex in determining emotions; includes the hippocampus and the amygdala.

LIME: The term generally used to describe ground limestone (calcium carbonate), hydrated lime (calcium hydroxide), or burned lime (calcium oxide).

LIME SOFTENING: Lime softening is primarily used to "soften" water—that is to remove calcium and magnesium mineral salts. But it also removes harmful toxins like radon and arsenic. Though there is no consensus, some studies have even suggested that lime softening is effective at removal of Giardia. Hard water is a common condition responsible for numerous problems. Users often recognize hard water because it prevents their soap from lathering properly. However, it can also cause buildup ("scale") in hot water heaters, boilers, and hot water pipes. Because of these inconveniences, many treatment facilities use lime softening to soften hard water for consumer use. Before lime softening can be used, managers must determine the softening chemistry required. This is a relatively easy task for groundwater sources, which remain more constant in their composition. Surface waters, however, fluctuate widely in quality and may require frequent changes to the softening chemical mix. In lime softening, lime and sometimes sodium carbonate are added to the water as it enters a combination solids contact clarifier. This raises the pH (i.e., increases alkalinity) and leads to the precipitation of calcium carbonate. Later, the pH of the effluent from the clarifier is reduced again, and the water is then filtered through a granular media filter. The water chemistry requirements of these systems require knowledgeable operators, which may make lime softening an economic challenge for some very small systems.

LIME STABILIZATION: The addition of lime to untreated sludge to raise the pH to 12 for a minimum of 2 hours to chemically inactivate microorganisms.

LINKED GENES: Genes that are located on the same chromosomes.

LIPID: One of a family of compounds, including fats, phospholipids, and steroids, that are insoluble in water.

LIPOPROTEIN: A protein bonded to a lipid; includes the low-density lipoproteins (LDLs) and high-density lipoproteins (HDLs) that transport fats and cholesterol in the blood.

LIPOSOME: Liposomes are vesicles (spherules) in which the lipid molecules are spontaneously arranged into bilayers with hydrophilic groups exposed to water molecules both outside the vesicle and in the core.

LISTED HAZARDOUS WASTE: The designation for a waste material that appears on an EPA list of specific hazardous wastes or hazardous waste categories.

LOCUS: A particular place along the length of a certain chromosome where a specified allele is located.

LOGISTIC POPULATION GROWTH: A model describing population growth that levels off as population size approaches carrying capacity.

L.O.T.O.: If a piece of equipment is locked out, the key to the lock-out device the key should be held by the person who is working on the equipment. The tag is an identification device and the lock is a physical restraint.

LYMPHOCYTE: Lymphocytes (lymph cells, lympho- leukocytes) are a type of leukocyte (white blood cell) responsible for the immune response. There are two classes of lymphocytes: 1) the B- cells, when presented with a foreign chemical entity (antigen), change into antibody producing plasma cells; and, 2) the T- cells interact directly with foreign invaders such as bacteria and viruses. The T- cells express various surface marker macromolecules. For example, CD4+ is the notation for a specific expressed T- cell surface marker that can be identified by assay.

LYSIS: The destruction of a cell by rupture of the plasma membrane.

LYSOGENIC CYCLE: A type of viral replication cycle in which the viral genome becomes incorporated into the bacterial host chromosome as a prophage.

LYSOSOME: A membrane-bounded organelle found in eukaryotic cells (other than plants). Lysosomes contain a mixture of enzymes that can digest most of the macromolecules found in the rest of the cell.

LYSOZYME: An enzyme in perspiration, tears, and saliva that attacks bacterial cell walls.

LYTIC CYCLE: A type of viral replication cycle resulting in the release of new phages by death or lysis of the host cell.

M-ENDO BROTH: The coliform group are used as indicators of fecal pollution in water, for assessing the effectiveness of water treatment and disinfection, and for monitoring water quality. m-Endo Broth is used for selectively isolating coliform bacteria from water and other specimens using the membrane filtration technique. m-Endo Broth is prepared according to the formula of Fifield and Schaufus.¹ It is recommended by the American Public Health Association in standard total coliform membrane filtration procedure for testing water, wastewater, and foods.^{2,3} The US EPA specifies using m-Endo Broth in the total coliform methods for testing water using single-step, two-step, and delayed incubation membrane filtration methods.

M PHASE: The mitotic phase of the cell cycle, which includes mitosis and cytokinesis.

MACROEVOLUTION: Evolutionary change on a grand scale, encompassing the origin of novel designs, evolutionary trends, adaptive radiation, and mass extinction.

MACROMOLECULE: A giant molecule of living matter formed by the joining of smaller molecules, usually by condensation synthesis. Polysaccharides, proteins, and nucleic acids are macromolecules.

MACROPHAGE: An amoeboid cell that moves through tissue fibers, engulfing bacteria and dead cells by phagocytosis.

MAGNESIUM HARDNESS: Measure of the magnesium salts dissolved in water – it is not a factor in water balance.

MAGNETIC STARTER: Is a type of motor starter should be used in an integrated circuit to control flow automatically.

MAJOR HISTOCOMPATIBILITY COMPLEX: A large set of cell surface antigens encoded by a family of genes. Foreign MHC markers trigger T-cell responses that may lead to rejection of transplanted tissues and organs.

MAKEUP WATER: Fluid introduced in a recirculating stream to maintain an equilibrium of temperature, solids concentration or other parameters. Also refers to the quantity of water required to make a solution.

MALIGNANT TUMOR: A cancerous growth; an abnormal growth whose cells multiply excessively, have altered surfaces, and may have unusual numbers of chromosomes and/or aberrant metabolic processes.

MALPHIGHIAN TUBULE: A unique excretory organ of insects that empties into the digestive tract, removes nitrogenous wastes from the blood, and functions in osmoregulation.

MANTLE: A heavy fold of tissue in mollusks that drapes over the visceral mass and may secrete a shell.

MARBLE AND LANGELETT TESTS: Are used to measure or determine the corrosiveness of a water source.

MASS NUMBER: The sum of the number of protons plus the number of neutrons in the nucleus of an atom; unique for each element and designated by a superscript to the left of the elemental symbol.

MATRIX SPIKE (MS): A sample prepared by adding a known quantity of organisms to a specified amount of sample matrix for which an independent estimate of target analyte concentration is available. A matrix spike is used to determine the effect of the matrix on a method's recovery efficiency.

MATRIX: The nonliving component of connective tissue, consisting of a web of fibers embedded in homogeneous ground substance that may be liquid, jellylike, or solid.

MATTER: Anything that takes up space and has mass.

MAXIMUM CONTAMINANT LEVEL (MCLs): The maximum allowable level of a contaminant

MECHANICAL SEAL: A mechanical device used to control leakage from the stuffing box of a pump. Usually made of two flat surfaces, one of which rotates on the shaft. The two flat surfaces are of such tolerances as to prevent the passage of water between them. Held in place with spring pressure.

MECHANORECEPTOR: A sensory receptor that detects physical deformations in the body environment associated with pressure, touch, stretch, motion, and sound.

MEDIAN BODIES: Prominent, dark-staining, paired organelles consisting of microtubules and found in the posterior half of *Giardia*. In *G. intestinalis* (from humans), these structures often have a claw-hammer shape, while in *G. muris* (from mice), the median bodies are round.

MEDIUM WATER SYSTEM: More than 3,300 persons and 50,000 or fewer persons.

MEDULLA OBLONGATA: The lowest part of the vertebrate brain; a swelling of the hindbrain dorsal to the anterior spinal cord that controls autonomic, homeostatic functions, including breathing, heart and blood vessel activity, swallowing, digestion, and vomiting.

MEDUSA: The floating, flattened, mouth-down version of the cnidarian body plan. The alternate form is the polyp.

MEGAPASCAL: A unit of pressure equivalent to 10 atmospheres of pressure.

MEGGER: Used to test the insulation resistance on a motor.

MEIOSIS: A two-stage type of cell division in sexually reproducing organisms that results in gametes with half the chromosome number of the original cell.

MEMBRANE: A thin barrier that permits passage of particles of a certain size or of particular physical or chemical properties.

MEMBRANE POTENTIAL: The charge difference between the cytoplasm and extracellular fluid in all cells, due to the differential distribution of ions. Membrane potential affects the activity of excitable cells and the transmembrane movement of all charged substances.

MESENTERIES: Membranes that suspend many of the organs of vertebrates inside fluid-filled body cavities.

MESODERM: The middle primary germ layer of an early embryo that develops into the notochord, the lining of the coelom, muscles, skeleton, gonads, kidneys and most of the circulatory system.

MESOSOME: A localized infolding of the plasma membrane of a bacterium.

MESSENGER: (RNA) A type of RNA synthesized from DNA in the genetic material that attaches to ribosomes in the cytoplasm and specifies the primary structure of a protein.

METABOLISM: The sum total of the chemical and physical changes constantly taking place in living substances.

METALLOID: Metalloid is a term used in chemistry when classifying the chemical elements. On the basis of their general physical and chemical properties, nearly every element in the periodic table can be termed either a metal or a nonmetal. A few elements with intermediate properties are, however, referred to as metalloids. (In Greek metallon = metal and eidos = sort) There is no rigorous definition of the term, but the following properties are usually considered characteristic of metalloids:

- * metalloids often form amphoteric oxides.

- * metalloids often behave as semiconductors (B, Si, Ge) to semimetals (e.g. Sb).

The concepts of metalloid and semiconductor should not be confused. Metalloid refers to the properties of certain elements in relation to the periodic table. Semiconductor refers to the physical properties of materials (including alloys, compounds) and there is only partial overlap between the two. The following elements are generally considered metalloids:

- * Boron (B)

- * Silicon (Si)

- * Germanium (Ge)

- * Arsenic (As)

- * Antimony (Sb)

- * Tellurium (Te)

METAMORPHOSIS: The resurgence of development in an animal larva that transforms it into a sexually mature adult.

METANEPHRIDIUM: A type of excretory tubule in annelid worms that has internal openings called nephrostomes that collect body fluids and external openings called nephridiopores.

METASTASIS: The spread of cancer cells beyond their original site.

METAZOAN: A multicellular animal. Among important distinguishing characteristics of metazoa are cell differentiation and intercellular communication. For certain multicellular colonial entities such as sponges, some biologists prefer the term "parazoa".

METHANE: Methane is a chemical compound with the molecular formula CH₄. It is the simplest alkane, and the principal component of natural gas. Methane's bond angles are 109.5 degrees. Burning methane in the presence of oxygen produces carbon dioxide and water. The relative abundance of methane and its clean burning process makes it a very attractive fuel. However, because it is a gas at normal temperature and pressure, methane is difficult to transport from its source. In its natural gas form, it is generally transported in bulk by pipeline or LNG carriers; few countries still transport it by truck. Methane is a relatively potent greenhouse gas with a high global warming potential of 72 (averaged over 20 years) or 25 (averaged over 100 years).[1] Methane in the atmosphere is eventually oxidized, producing carbon dioxide and water. As a result, methane in the atmosphere has a half-life of seven years (if no methane was added, then every seven years, the amount of methane would halve). The abundance of methane in the Earth's atmosphere in 1998 was 1745 parts per billion, up from 700 ppb in 1750. In the same time period, CO₂ increased from 278 to 365 parts per million. The radiative forcing effect due to this increase in methane abundance is about one-third of that of the CO₂ increase. In addition, there is a large, but unknown, amount of methane in methane clathrates in the ocean floors. Global warming could release this methane, which could cause a further sharp rise in global temperatures. Such releases of methane may have been a major factor in previous

major extinction events. The Earth's crust also contains huge amounts of methane. Large amounts of methane are produced anaerobically by methanogenesis. Other sources include mud volcanoes which are connected with deep geological faults.

METHOD BLANK: An aliquot of reagent water that is treated exactly as a sample, including exposure to all glassware, equipment, solvents, and procedures that are used with samples. The method blank is used to determine if analytes or interferences are present in the laboratory environment, the reagents, or the apparatus.

Mg/L: Stands for "milligrams per liter." A common unit of chemical concentration. It expresses the mass of a chemical that is present in a given volume of water. A milligram (one one-thousandth of a gram) is equivalent to about 18 grains of table salt. A liter is equivalent to about one quart.

MICROBE OR MICROBIAL: Any minute, simple, single-celled form of life, especially one that causes disease.

MICROBIAL CONTAMINANTS: Microscopic organisms present in untreated water that can cause waterborne diseases.

MICROBIOLOGICAL: Is a type of analysis in which a composite sample unacceptable.

MICROBODY: A small organelle, bounded by a single membrane and possessing a granular interior. Peroxisomes and glyoxysomes are types of microbodies.

MICROEVOLUTION: A change in the gene pool of a population over a succession of generations.

MICROFILAMENT: Minute fibrous structure generally composed of actin found in the cytoplasm of eukaryotic cells. They play a role in motion within cells.

MICROFILTRATION: A low pressure membrane filtration process that removes suspended solids and colloids generally larger than 0.1 micron diameter.

MICROORGANISMS: Very small animals and plants that are too small to be seen by the naked eye and must be observed using a microscope. Microorganisms in water include algae, bacteria, viruses, and protozoa. Algae growing in surface waters can cause off-taste and odor by producing the chemicals MIB and geosmin. Certain types of bacteria, viruses, and protozoa can cause disease in humans. Bacteria are the most common microorganisms found in treated drinking water. The great majority of bacteria are not harmful. In fact, humans would not be able to live without the bacteria that inhabit the intestines. However, certain types of bacteria called coliform bacteria can signal the presence of possible drinking water contamination.

MICROSCOPE: An instrument which magnifies images either by using lenses in an optical system to bend light (light microscope) or electromagnets to direct the movement of electrons (electron microscope).

MICROTUBULE: A minute tubular structure found in centrioles, spindle apparatus, cilia, flagella, and other places in the cytoplasm of eukaryotic cells. Microtubules play a role in movement and maintenance of shape.

MICROVILLUS: Collectively, fine, fingerlike projections of the epithelial cells in the lumen of the small intestine that increase its surface area.

MILLIGRAMS PER LITER: (mg/L) A common unit of measurement of the concentration of a material in solution.

MILLILITER: One one-thousandth of a liter; A liter is a little more than a quart. A milliliter is about two drops from an eye dropper.

MIMICRY: A phenomenon in which one species benefits by a superficial resemblance to an unrelated species. A predator or species of prey may gain a significant advantage through mimicry.

MISCIBLE: Capable of being mixed together.

MISSENSE: (mutation) The most common type of mutation involving a base- pair substitution within a gene that changes a codon, but the new codon makes sense, in that it still codes for an amino acid.

MITOCHONDRIAL MATRIX: The compartment of the mitochondrion enclosed by the inner membrane and containing enzymes and substrates for the Krebs cycle.

MITOCHONDRION: An organelle that occurs in eukaryotic cells and contains the enzymes of the citric acid cycle, the respiratory chain, and oxidative phosphorylation. A mitochondrion is bounded by a double membrane.

MITOSIS: A process of cell division in eukaryotic cells conventionally divided into the growth period (interphase) and four stages: prophase, metaphase, anaphase, and telophase. The stages conserve chromosome number by equally allocating replicated chromosomes to each of the daughter cells.

MIXED LIQUOR SUSPENDED SOLIDS: Suspended solids in the mixture of wastewater and activated sludge undergoing aeration in the aeration basin.

MODEM SYNTHESIS: A comprehensive theory of evolution emphasizing natural selection, gradualism, and populations as the fundamental units of evolutionary change; also called Neo-Darwinism.

MOISTURE: If a material is hygroscopic, it must be protected from water.

MOISTURE AND POTASSIUM PERMANGANATE: The combination of moisture and potassium permanganate produces heat.

MOLARITY: A common measure of solute concentration, referring to the number of moles of solute in 1 L of solution.

MOLD: A rapidly growing, asexually reproducing fungus.

MOLE: The number of grams of a substance that equals its molecular weight in daltons and contains Avogadro's number of molecules.

MOLECULAR FORMULA: A type of molecular notation indicating only the quantity of the constituent atoms.

MOLECULAR WEIGHT: The molecular mass (abbreviated Mr) of a substance, formerly also called molecular weight and abbreviated as MW, is the mass of one molecule of that substance, relative to the unified atomic mass unit u (equal to 1/12 the mass of one atom of carbon-12). This is distinct from the relative molecular mass of a molecule, which is the ratio of the mass of that molecule to 1/12 of the mass of carbon 12 and is a dimensionless number. Relative molecular mass is abbreviated to Mr.

MOLECULE: Two or more atoms of one or more elements held together by ionic or covalent chemical bonds.

MOLTING: A process in arthropods in which the exoskeleton is shed at intervals to allow growth by secretion of a larger exoskeleton.

MONERA: The kingdom of life forms that includes all of the bacteria.

MONOCLONAL ANTIBODY: A defensive protein produced by cells descended from a single cell; an antibody that is secreted by a clone of cells and, consequently, is specific for a single antigenic determinant.

MONOECIOUS: Referring to an organism having the capacity of producing both sperm and eggs.

MONOHYBRID CROSS: A breeding experiment that employs parental varieties differing in a single character.

MONOMER: A small molecule, two or more of which can be combined to form oligomers (consisting of a few monomers) or polymers (consisting of many monomers).

MONOPHYLETIC: A term used to describe any taxon derived from a single ancestral form that gave rise to no species in other taxa.

MONOSACCHARIDE: A simple sugar; a monomer.

MONOZYGOTIC TWINS: Monozygotic twins are genetically identical, derived from the division and autonomous development of a single zygote (fertilized egg).

MORPHOGENESIS: The development of body shape and organization during ontogeny.

MORPHOSPECIES: Species defined by their anatomical features.

MOSAIC EVOLUTION: The evolution of different features of an organism at different rates.

MOSAIC: A pattern of development, such as that of a mollusk, in which the early blastomeres each give rise to a specific part of the embryo. In some animals, the fate of the blastomeres is established in the zygote.

MOTOR NERVOUS SYSTEM: In vertebrates, the component of the peripheral nervous system that transmits signals from the central nervous system to effector cells.

MPF: M: phase promoting factor: A protein complex required for a cell to progress from late interphase to mitosis; the active form consists of cyclin and cdc2, a protein kinase.

M.S.D.S.: A safety document must an employer provide to an operator upon request.

MUCOSA: Refers to the mucous tissue lining various tubular structures in the body.

MUD BALLS IN FILTER MEDIA: Is a possible result of an ineffective or inadequate filter backwash.

MULLERIAN MIMICRY: A mutual mimicry by two unpalatable species.

MULTIGENE FAMILY: A collection of genes with similar or identical sequences, presumably of common origin.

MUNICIPAL WASTE: The combined solid and liquid waste from residential, commercial and industrial sources.

MUNICIPAL WASTEWATER TREATMENT PLANT (MWTP): Treatment works designed to treat municipal wastewater.

MURIATIC ACID: An acid used to reduce pH and alkalinity. Also used to remove stain and scale.

MUST: This action, activity, or procedural step is required.

MUTAGEN: A chemical or physical agent that interacts with DNA and causes a mutation.

MUTAGENESIS: The creation of mutations.

MUTATION: A spontaneous or induced change in a gene's or chromosome's structure or number. The resulting individual is termed a mutant.

MUTUALISM: A symbiotic relationship in which both the host and the symbiont benefit.

MYCELIUM: The densely branched network of hyphae in a fungus.

MYCOBACTERIUM: Pleomorphic spherical or rod-shaped, frequently branching, no gram stain, aerobic; commonly form yellow pigments; include Mycobacterium tuberculosis, cause of tuberculosis.

MYCOPLASMA: Spherical, commonly forming branching chains, no gram stain, aerobic but can live in certain anaerobic conditions; without cell walls yet structurally resistant to lysis; among smallest of bacteria; named for superficial resemblance to fungal hyphae (myco-means "fungus").

MYELIN SHEATH: An insulating coat of cell membrane from Schwann cells that is interrupted by nodes of Ranvier where saltatory conduction occurs.

MYOFIBRILS: Fibrils arranged in longitudinal bundles in muscle cells (fibers); composed of thin filaments of actin and a regulatory protein and thick filaments of myosin.

MYOGLOBIN: An oxygen-storing, pigmented protein in muscle cells.

MYOSIN: A type of protein filament that interacts with actin filaments to cause cell movement, such as contraction in muscle cells.

NAD⁺: Nicotinamide adenine dinucleotide (oxidized); a coenzyme present in all cells that assists enzymes in transferring electrons during the redox reactions of metabolism.

NANO-FILTRATION: A specialty membrane filtration process that rejects solutes larger than approximately one nanometer (10 angstroms) in size.

NANOMETER: A unit of measure (length). 1 nm is equal to 1×10^{-9} m, or 1/1,000,000 mm.

NaOCl: Is the molecular formula of Sodium hypochlorite.

NaOH: Is the molecular formula of Sodium hydroxide.

NATURAL ORGANIC MATTER: Organic matter present in natural waters.

NEGATIVE CONTROL: See Method blank.

NEGATIVE FEEDBACK: A primary mechanism of homeostasis, whereby a change in a physiological variable that is being monitored triggers a response that counteracts the initial fluctuation.

NEURAMINIDASE: A surface enzyme possessed by some influenza viruses which help the virus penetrate the mucus layer protecting the respiratory epithelium and also plays a role in budding of new virus particles from infected cells.

NEUTRALIZATION: The chemical process that produces a solution that is neither acidic nor alkaline. Usually with a pH between 6 and 8.

NEURON: A nerve cell; the fundamental unit of the nervous system, having structure and properties that allow it to conduct signals by taking advantage of the electrical charge across its cell membrane.

NEUROSECRETORY CELLS: Cells that receive signals from other nerve cells, but instead of signaling to an adjacent nerve cell or muscle, release hormones into the blood stream.

NEUROTRANSMITTER: The chemical messenger released from the synaptic terminals of a neuron at a chemical synapse that diffuses across the synaptic cleft and binds to and stimulates the postsynaptic cell.

NEUTRAL VARIATION: Genetic diversity that confers no apparent selective advantage.

NEUTRALIZATION REACTIONS: Chemical reactions between acids and bases where water is an end product.

NEUTRON: An uncharged subatomic particle of about the same size and mass as a proton.

NH₃: The molecular formula of Ammonia.

NH₄⁺: The molecular formula of the Ammonium ion.

NITRATES: A dissolved form of nitrogen found in fertilizers and sewage by-products that may leach into groundwater and other water sources. Nitrates may also occur naturally in some waters. Over time, nitrates can accumulate in aquifers and contaminate groundwater.

NITROGEN: Nitrogen is a nonmetal, with an electronegativity of 3.0. It has five electrons in its outer shell and is therefore trivalent in most compounds. The triple bond in molecular nitrogen (N₂) is one of the strongest in nature. The resulting difficulty of converting (N₂) into other compounds, and the ease (and associated high energy release) of converting nitrogen compounds into elemental N₂, have dominated the role of nitrogen in both nature and human economic activities. At atmospheric pressure molecular nitrogen condenses (liquefies) at 77 K (-195.8 °C) and freezes at 63 K (-210.0 °C) into the beta hexagonal close-packed crystal allotropic form. Below 35.4 K (-237.6 °C) nitrogen assumes the alpha cubic crystal allotropic form. Liquid nitrogen, a fluid resembling water, but with 80.8% of the density, is a common cryogen. Unstable allotropes of nitrogen consisting of more than two nitrogen atoms have been produced in the laboratory, like N₃ and N₄.^[1] Under extremely high pressures (1.1 million atm) and high temperatures (2000 K), as produced under diamond anvil conditions, nitrogen polymerizes into the single bonded diamond crystal structure, an allotrope nicknamed "nitrogen diamond."

NITROGEN AND PHOSPHORUS: Pairs of elements and major plant nutrients that cause algae to grow.

NITROGEN-FIXING: Rod-shaped, gram-negative, aerobic; convert atmospheric nitrogen gas to ammonium in soil; include *Azotobacter*, a common genus.

NO₃⁻: The molecular formula of the Nitrate ion.

NOMENCLATURE: The method of assigning names in the classification of organisms.

NON-CARBONATE HARDNESS: The portion of the total hardness in excess of the alkalinity.

NON-CARBONATE IONS: Water contains non-carbonate ions if it cannot be softened to a desired level through the use of lime only.

NON-POINT SOURCE POLLUTION: Air pollution may leave contaminants on highway surfaces. This non-point source pollution adversely impacts reservoir water and groundwater quality.

NONCOMPETITIVE INHIBITOR: A substance that reduces the activity of an enzyme by binding to a location remote from the active site, changing its conformation so that it no longer binds to the substrate.

NONCYCLIC ELECTRON FLOW: A route of electron flow during the light reactions of photosynthesis that involves both photosystems and produces ATP, NADPH, and oxygen; the net electron flow is from water to NADP⁺.

NONCYCLIC PHOTOPHOSPHORYLATION: The production of ATP by noncyclic electron flow.

NONDISJUNCTION: An accident of meiosis or mitosis, in which both members of a pair of homologous chromosomes or both sister chromatids fail to separate normally.

NONPOLAR: Electrically symmetrical. For example, in many molecules with covalent bonds, the electrons are shared equally; the poles are electrically neutral.

NONSENSE MUTATION: A mutation that changes an amino acid codon to one of the three stop codons, resulting in a shorter and usually nonfunctional protein.

NORM OF REACTION: The range of phenotypic possibilities for a single genotype, as influenced by the environment.

NORMALITY: It is the number of equivalent weights of solute per liter of solution. Normality highlights the chemical nature of salts: in solution, salts dissociate into distinct reactive species (ions such as H⁺, Fe³⁺, or Cl⁻). Normality accounts for any discrepancy between the concentrations of the various ionic species in a solution. For example, in a salt such as MgCl₂, there are two moles of Cl⁻ for every mole of Mg²⁺, so the concentration of Cl⁻ as well as of Mg²⁺ is said to be 2 N (read: "two normal"). Further examples are given below. A normal is one gram equivalent of a solute per liter of solution. The definition of a gram equivalent varies depending on the type of chemical reaction that is discussed - it can refer to acids, bases, redox species, and ions that will precipitate. It is critical to note that normality measures a single ion which takes part in an overall solute. For example, one could determine the normality of hydroxide or sodium in an aqueous solution of sodium hydroxide, but the normality of sodium hydroxide itself has no meaning.

NTU: (Nephelometric turbidity unit): A measure of the clarity or cloudiness of water.

NUCLEAR: 1) (envelope) The surface, consisting of two layers of membrane, that encloses the nucleus of eukaryotic cells. 2) (pore) An opening of the nuclear envelope which allows for the movement of materials between the nucleus and surrounding cytoplasm.

NUCLEASE: This term refers to any enzyme that acts on nucleic acids, e.g., Dnase, Rnase, endonuclease, etc.

NUCLEIC: (acid) A polymer composed of nucleotides that are joined by covalent bonds (phosphodiester linkages) between the phosphate of one nucleotide and the sugar of the next nucleotide.

NUCLEOID: The region that harbors the chromosome of a prokaryotic cell. Unlike the eukaryotic nucleus, it is not bounded by a membrane.

NUCLEOLUS (pl. nucleoli): A specialized structure in the nucleus, formed from various chromosomes and active in the synthesis of ribosomes.

NUCLELUS: A small, generally spherical body found within the nucleus of eukaryotic cells. The site of ribosomal RNA synthesis.

NUCLEOSIDE: An organic molecule consisting of a nitrogenous base joined to a five- carbon sugar.

NUCLEOSOME: The basic, beadlike unit of DNA packaging in eukaryotes, consisting of a segment of DNA wound around a protein core composed of two copies of each of four types of histone.

NUCLEOTIDE: The basic chemical unit (monomer) of a nucleic acid. A nucleotide in RNA consists of one of four nitrogenous bases linked to ribose, which in turn is linked to phosphate. In DNA, deoxyribose is present instead of ribose.

NUCLEUS: A membrane-bound organelle containing genetic material. Nuclei are a prominent internal structure seen both in *Cryptosporidium* oocysts and *Giardia* cysts. In *Cryptosporidium* oocysts, there is one nucleus per sporozoite. One to four nuclei can be seen in *Giardia* cysts.

NUCLEUS: The membrane bound organelle of eukaryotic cells that contains the cell's genetic material. Also the central region of an atom composed of protons and neutrons.

NULL: In the scientific method, the hypothesis which one attempts to falsify.

O³: The molecular formula of ozone.

OLIGOTROPHIC: A reservoir that is nutrient-poor and contains little plant or animal life. An oligotrophic ecosystem or environment is one that offers little to sustain life. The term is commonly utilized to describe bodies of water or soils with very low nutrient levels. It derives etymologically from the Greek oligo (small, little, few) and trophe (nutrients, food). Oligotrophic environments are of special interest for the alternative energy sources and survival strategies upon which life could rely.

ONGOING PRECISION AND RECOVERY (OPR) STANDARD: A method blank spiked with known quantities of analytes. The OPR is analyzed exactly like a sample. Its purpose is to assure that the results produced by the laboratory remain within the limits specified in this method for precision and recovery.

OOCYST AND CYST SPIKING SUSPENSION: See Spiking suspension.

OOCYST AND CYST STOCK SUSPENSION: See Stock suspension.

OOCYST: The encysted zygote of some sporozoa; e.g., *Cryptosporidium*. The oocyst is a phase or form of the organism produced as a normal part of the life cycle of the organism. It is characterized by a thick and environmentally resistant outer wall.

ORGANIC: Relating to, or derived from, a living thing. A description of a substance that contains carbon atoms linked together by carbon-carbon bonds.

ORGANIC MATTER: Substances containing carbon compounds, usually of animal or vegetable origin.

ORGANIC PRESURSORS: Natural or man-made compounds with chemical structures based upon carbon that, upon combination with chlorine, leading to trihalomethane formation.

OSMOSIS: Osmosis is the process by which water moves across a semi permeable membrane from a low concentration solute to a high concentration solute to satisfy the pressure differences caused by the solute.

OVER-RANGE PROTECTION DEVICES: Mechanical dampers, snubbers and an air cushion chamber are examples of surging and overrange protection devices.

OXIDE: An oxide is a chemical compound containing at least one oxygen atom as well as at least one other element. Most of the Earth's crust consists of oxides. Oxides result when elements are oxidized by oxygen in air. Combustion of hydrocarbons affords the two principal oxides of carbon, carbon monoxide and carbon dioxide. Even materials that are considered to be pure elements often contain a coating of oxides. For example, aluminum foil has a thin skin of Al_2O_3 that protects the foil from further corrosion. Virtually all elements burn in an atmosphere of oxygen. In the presence of water and oxygen (or simply air), some elements - lithium, sodium, potassium, rubidium, caesium, strontium and barium - react rapidly, even dangerously to give the hydroxides. In part for this reason, alkali and alkaline earth metals are not found in nature in their metallic, i.e., native, form. Caesium is so reactive with oxygen that it is used as a getter in vacuum tubes, and solutions of potassium and sodium, so called NaK are used to deoxygenate and dehydrate some organic solvents. The surface of most metals consists of oxides and hydroxides in the presence of air. A well-known example is aluminum foil, which is coated with a thin film of aluminum oxide that passivates the metal, slowing further corrosion. The aluminum oxide layer can be built to greater thickness by the process of electrolytic anodizing. Although solid magnesium and aluminum react slowly with oxygen at STP, they, like most metals, will burn in air, generating very high temperatures. As a consequence, finely divided powders of most metals can be dangerously explosive in air.

OXIDIZED:

1. to convert (an element) into an oxide; combine with oxygen.
 2. to cover with a coating of oxide or rust.
 3. to take away hydrogen, as by the action of oxygen; add oxygen or any nonmetal.
 4. to remove electrons from (an atom or molecule), thereby increasing the valence. Compare REDUCE (def. 12).
- verb (used without object)
5. to become oxidized.
 6. (esp. of white wine) to lose freshness after prolonged exposure to air and often to darken in color.

OXIDIZING: The process of breaking down organic wastes into simpler elemental forms or by products. Also used to separate combined chlorine and convert it into free chlorine.

OXYGEN DEFICIENT ENVIRONMENT: One of the most dangerous threats to an operator upon entering a manhole.

OZONE: Ozone or trioxygen (O_3) is a triatomic molecule, consisting of three oxygen atoms. It is an allotrope of oxygen that is much less stable than the diatomic O_2 . Ground-level ozone is an air pollutant with harmful effects on the respiratory systems of animals. Ozone in the upper atmosphere filters potentially damaging ultraviolet light from reaching the Earth's surface. It is present in low concentrations throughout the Earth's atmosphere. It has many industrial and consumer applications. Ozone, the first allotrope of a chemical element to be recognized by science, was proposed as a distinct chemical compound by Christian Friedrich Schönbein in 1840, who named it after the Greek word for smell (ozein), from the peculiar odor in lightning storms.[The formula for ozone, O_3 , was not determined until 1865 by Jacques-Louis Soret and confirmed by Schönbein in 1867. Ozone is a powerful oxidizing agent, far better than dioxygen. It is also unstable at high concentrations, decaying to ordinary diatomic oxygen (in about half an hour in atmospheric conditions):
 $2 O_3 = 3 O_2$

This reaction proceeds more rapidly with increasing temperature and decreasing pressure. Deflagration of ozone can be triggered by a spark, and can occur in ozone concentrations of 10 wt% or higher.

PACKING: Material, usually of woven fiber, placed in rings around the shaft of a pump and used to control the leakage from the stuffing box.

PAINT FILTER TEST: Test to determine free water content of sludge or dewatered solids sample. Usually used as the criteria for admission to a landfill.

PARAMECIUM: Paramecia are a group of unicellular ciliate protozoa formerly known as slipper animalcules from their slipper shape. They are commonly studied as a representative of the ciliate group. Simple cilia cover the body which allows the cell to move with a synchronous motion (like a caterpillar). There is also a deep oral groove containing inconspicuous compound oral cilia (as found in other peniculids) that is used to draw food inside. They generally feed upon bacteria and other small cells. Osmoregulation is carried out by a pair of contractile vacuoles, which actively expel water absorbed by osmosis from their surroundings. Paramecia are widespread in freshwater environments, and are especially common in scums. Paramecia are attracted by acidic conditions. Certain single-celled eukaryotes, such as Paramecium, are examples for exceptions to the universality of the genetic code (translation systems where a few codons differ from the standard ones).

PARTS PER MILLION (PPM): A common unit of measure used to express the number of parts of a substance contained within a million parts of a liquid, solid, or gas.

PASTEURIZATION: A process for killing pathogenic organisms by applying heat for a specific period of time.

PATHOGENS: Disease-causing pathogens; waterborne pathogens A pathogen may contaminate water and cause waterborne disease.

Pb: The chemical symbol of Lead.

PCE: abbr. perchloroethylene. Known also as perc or tetrachloroethylene, perchloroethylene is a clear, colorless liquid with a distinctive, somewhat ether-like odor. It is non-flammable, having no measurable flashpoint or flammable limits in air. Effective over a wide range of applications, perchloroethylene is supported by closed loop transfer systems, stabilizers and employee exposure monitoring.

pCi/L: Picocuries per liter A curie is the amount of radiation released by a set amount of a certain compound. A picocurie is one quadrillionth of a curie.

PEAK DEMAND: The maximum momentary load placed on a water treatment plant, pumping station or distribution system.

PERKINESIS: The aggregation resulting from random thermal motion of fluid molecules.

PERMEATE: The term for water which has passed through the membrane of a reverse osmosis unit. The liquid that passes through a membrane.

pH: A unit of measure which describes the degree of acidity or alkalinity of a solution. The pH scale runs from 0 to 14 with 7 being the mid-point or neutral. A pH of less than 7 is on the acid side of the scale with 0 as the point of greatest acid activity. A pH of more than 7 is on the basic (alkaline) side of the scale with 14 as the point of greatest basic activity. The term pH is derived from "p", the mathematical symbol of the negative logarithm, and "H", the chemical symbol of Hydrogen. The definition of pH is the negative logarithm of the Hydrogen ion activity. $pH = -\log[H^+]$.

pH OF SATURATION: The ideal pH for perfect water balance in relation to a particular total alkalinity level and a particular calcium hardness level, at a particular temperature. The pH where the Langelier Index equals zero.

PHENOLPHTHALEIN/TOTAL ALKALINITY: The relationship between the alkalinity constituent's bicarbonate, carbonate, and hydroxide can be based on the P and T alkalinity measurement.

PHENOL RED: Chemical reagent used for testing pH in the range of 6.8 - 8.4.

PHOSPHATE, NITRATE AND ORGANIC NITROGEN: Nutrients in a domestic water supply reservoir may cause water quality problems if they occur in moderate or large quantities.

PHYSICAL CHEMICAL TREATMENT: Treatment processes that are non-biological in nature.

PICOCURIE: A unit of radioactivity. "Pico" is a metric prefix that means one one-millionth of one one-millionth. A picocurie is one one-millionth of one one-millionth of a Curie. A Curie is that quantity of any radioactive substance that undergoes 37 billion nuclear disintegrations per second. Thus a picocurie is that quantity of any radioactive substance that undergoes 0.037 nuclear disintegrations per second.

PIEZOMETRIC SURFACE: See potentiometric surface.

PIN FLOC: Small flocculated particle size.

PLATE AND FRAME PRESS: A batch process dewatering device in which sludge is pumped under high pressure through a series of parallel plates, in which a chamber is created between the plates. Each plate is fitted with filter cloth and the solids are collected in the chambers and the water is filtered from the sludge.

POINT SOURCE DISCHARGE: A pipe, ditch, channel or other container from which pollutants may be discharged.

POLLUTANT: A substance, organism or energy form present in amounts that impair or threaten an ecosystem to the extent that its current or future uses are prevented.

POLLUTION: To make something unclean or impure. See Contaminated.

POLYMER: A type of chemical when combined with other types of coagulants aid in binding small suspended particles to larger particles to help in the settling and filtering processes. Chemical used for flocculation in dewatering. Also known as a "polyelectrolyte" which is a substance made of giant molecules formed by the union of simple smaller molecules.

POLYPHOSPHATES: Chemicals that may be added to remove low levels of iron and manganese.

PORE SPACE: The interstitial space between sediments and fractures that is capable of storing and transmitting water.

POROSITY: A factor representing a rock, soil, or formations percentage of open space available for the percolation and storage of groundwater.

POSITIVE CONTROL: See Ongoing precision and recovery standard.

POST-CHLORINE: Where the water is chlorinated to make sure it holds a residual in the distribution system.

POST TREATMENT: Treatment of finished water or wastewater to further enhance its quality.

POTABLE: Good water which is safe for drinking or cooking purposes. Non-Potable: A liquid or water that is not approved for drinking.

POTENTIAL ENERGY: The energy that a body has by virtue of its position or state enabling it to do work.

PPM: Abbreviation for parts per million.

PRE-CHLORINE: Where the raw water is dosed with a large concentration of chlorine.

PRE-CHLORINATION: The addition of chlorine before the filtration process will help:

- > Control algae and slime growth
- > Control mud ball formation
- > Improve coagulation
- > Precipitate iron

The addition of chlorine to the water prior to any other plant treatment processes.

PRECIPITATE: A solid that separates from a solution.

PRECIPITATION: The phenomenon that occurs when a substance held in solution passes out of solution into a solid form.

PRELIMINARY TREATMENT: Treatment steps including comminution, screening, grit removal, pre-aeration, and/or flow equalization that prepares wastewater influent for further treatment.

PRESSURE: Pressure is defined as force per unit area. It is usually more convenient to use pressure rather than force to describe the influences upon fluid behavior. The standard unit for pressure is the Pascal, which is a Newton per square meter. For an object sitting on a surface, the force pressing on the surface is the weight of the object, but in different orientations it might have a different area in contact with the surface and therefore exert a different pressure.

PRESSURE FILTER: Filter unit enclosed in a vessel that may be operated under pressure.

PRESSURE HEAD: The height of a column of water capable of being maintained by pressure. See also Total Head, Total Dynamic Head.

PRESSURE MEASUREMENT: Bourdon tube, Bellows gauge and Diaphragm are commonly used to measure pressure in waterworks systems. A Bellows-type sensor reacts to a change in pressure.

PREVENTION: To take action. Stop something before it happens.

PRIMARY CLARIFIER: Sedimentation basin that precedes secondary wastewater treatment.

PRIMARY SLUDGE: Sludge produced in a primary waste treatment unit.

PRIMARY TREATMENT: Treatment steps including sedimentation and/or fine screening to produce an effluent suitable for biological treatment.

PROCESS WASTEWATER: Wastewater generated during manufacture or production processes.

PROCESS WATER: Water that is used for, or comes in contact with an end product or the materials used in an end product.

PROPIONIC ACID: Rod-shaped, pleomorphic, gram-positive, anaerobic; ferment lactic acid; fermentation produces holes in Swiss cheese from the production of carbon dioxide.

PROTON, NEUTRON AND ELECTRON: Are the 3 fundamental particles of an atom.

PROTOZOA: Microscopic animals that occur as single cells. Some protozoa can cause disease in humans. Protozoa form cysts, which are specialized cells like eggs that are very resistant to chlorine. Cysts can survive the disinfection process, then "hatch" into normal cells that can cause disease. Protozoa must be removed from drinking water by filtration, because they cannot be effectively killed by chlorine.

PSEUDOMONAD: Rod-shaped (straight or curved) with polar flagella, gram-negative, aerobic; can use up to 100 different compounds for carbon and energy.

PUMPING LIFT: The height to which water must be pumped or lifted to, feet of head.

PTFE: Polytetrafluoroethylene.

QUANTITATIVE TRANSFER: The process of transferring a solution from one container to another using a pipette in which as much solution as possible is transferred, followed by rinsing of the walls of the source container with a small volume of rinsing solution (e.g., reagent water, buffer, etc.), followed by transfer of the rinsing solution, followed by a second rinse and transfer.

QUICKLIME: A calcium oxide material produced by calcining limestone to liberate carbon dioxide, also called "calcined lime" or "pebble lime", commonly used for pH adjustment. Chemical formula is CaO.

RAW TURBIDITY: The turbidity of the water coming to the treatment plant from the raw water source.

REAGENT: A substance used in a chemical reaction to measure, detect, examine, or produce other substances.

REDOX POTENTIAL: Reduction potential (also known as redox potential, oxidation / reduction potential or ORP) is the tendency of a chemical species to acquire electrons and thereby be reduced. Each species has its own intrinsic reduction potential; the more positive the potential, the greater the species' affinity for electrons and tendency to be reduced. In aqueous solutions, the reduction potential is the tendency of the solution to either gain or lose electrons when it is subject to change by introduction of a new species. A solution with a higher (more positive) reduction potential than the new species will have a tendency to gain electrons from the new species (i.e. to be reduced by oxidizing the new species) and a solution with a lower (more negative) reduction potential will have a tendency to lose electrons to the new species (i.e. to be oxidized by reducing the new species). Just as the transfer of hydrogen ions between chemical species determines the pH of an aqueous solution, the transfer of electrons between chemical species determines the reduction potential of an aqueous solution. Like pH, the reduction potential represents an intensity factor. It does not characterize the capacity of the system for oxidation or reduction, in much the same way that pH does not characterize the buffering capacity.

RELAY LOGIC: The name of a popular method of automatically controlling a pump, valve, chemical feeder, and other devices.

RESERVOIR: An impoundment used to store water.

RICKETTSIA: Spherical or rod-shaped, gram-negative, aerobic; cause Rocky Mountain spotted fever and typhus; closely related to Agrobacterium, a common gall-causing plant bacterium.

ROTIFER: Rotifers get their name (derived from Greek and meaning "wheel-bearer"; they have also been called wheel animalcules) from the corona, which is composed of several ciliated tufts around the mouth that in motion resemble a wheel. These create a current that sweeps food into the mouth, where it is chewed up by a characteristic pharynx (called the mastax) containing a tiny, calcified, jaw-like structure called the trophi. The cilia also pull the animal, when unattached, through the water. Most free-living forms have pairs of posterior toes to anchor themselves while feeding. Rotifers have bilateral symmetry and a variety of different shapes. There is a well-developed cuticle which may be thick and rigid, giving the animal a box-like shape, or flexible, giving the animal a worm-like shape; such rotifers are respectively called loricate and illoricate.

RAW SEWAGE: Untreated wastewater and its contents.

RAW SLUDGE: Undigested sludge recently removed from a sedimentation basin.

RAW WATER: Untreated surface or groundwater.

REAGENT WATER BLANK: see Method blank.

REAGENT WATER: Water demonstrated to be free from the analytes of interest and potentially interfering substances at the method detection limit for the analyte.

RECLAIMED WATER: Wastewater that has been treated to a level that allows for its reuse for a beneficial purpose.

RECLAMATION: The process of improving or restoring the condition of land or other material to a better or more useful state.

RECYCLING: The process by which recovered materials are transformed into new products.

RELATIVE STANDARD DEVIATION (RSD): The standard deviation divided by the mean times 100.

RESIDENCE TIME: The period of time that a volume of liquid remains in a tank or system.

RESPIRATION: Intake of oxygen and discharge of carbon dioxide as a result of biological oxidation.

RETURN ACTIVATED SLUDGE: Settled activated sludge that is returned to mix with raw or primary settled wastewater.

ROBERT HOOKE: Coined the term "cell" to describe the structures he saw while examining a piece of cork using a microscope.

ROTARY DRUM SCREEN: Cylindrical screen used to remove floatable and suspended solids.

RSD: See Relative standard deviation.

SANITARY SURVEY: Persons trained in public health engineering and the epidemiology of waterborne diseases should conduct the sanitary survey. The importance of a detailed sanitary survey of a new water source cannot be overemphasized. An on-site review of the water sources, facilities, equipment, operation, and maintenance of a public water systems for the purpose of evaluating the adequacy of the facilities for producing and distributing safe drinking water. The purpose of a non-regulatory sanitary survey is to identify possible biological and chemical pollutants which might affect a water supply.

SANITIZER: A disinfectant or chemical which disinfects (kills bacteria), kills algae and oxidizes organic matter.

SATURATION INDEX: See Langelier's Index.

SATURATOR: A device which produces a fluoride solution for the fluoride process. Crystal-grade types of sodium fluoride should be fed with a saturator. Overfeeding must be prevented to protect public health when using a fluoridation system.

SATURATED ZONE: Where an unconfined aquifer becomes saturated beneath the capillary fringe.

SCADA: A remote method of monitoring pumps and equipment. 130 degrees F is the maximum temperature that transmitting equipment is able to with stand. If the level controller may be set with too close a tolerance 45 could be the cause of a control system that is frequently turning a pump on and off.

SCALE: Crust of calcium carbonate, the result of unbalanced water. Hard insoluble minerals deposited (usually calcium bicarbonate) which forms on pool and spa surfaces and clog filters, heaters and pumps. Scale is caused by high calcium hardness and/or high pH. The regular use of stain prevention chemicals can prevent scale.

SCREENINGS PRESS: A mechanical press used to compact and/or dewater material removed from mechanical screening equipment.

SCROLL AND BASKET: The two basic types of centrifuges used in water treatment.

SCRUBBER: A device used to removal particulates or pollutant gases from combustion or chemical process exhaust streams.

SCUM: Floatable materials found on the surface of primary and secondary settling tanks consisting of food wastes, grease, fats, paper, foam, and similar matter.

SECONDARY CLARIFIER: A clarifier following a secondary treatment process, designed for gravity removal of suspended matter.

SECONDARY SLUDGE: The sludge from the secondary clarifier in a wastewater treatment plant.

SECONDARY TREATMENT: The treatment of wastewater through biological oxidation after primary treatment.

SEDIMENTATION: The removal of settleable suspended solids from water or wastewater by gravity in a quiescent basin or clarifier.

SEDIMENTATION BASIN: A quiescent tank used to remove suspended solids by gravity settling. Also called clarifiers or settling tanks, they are usually equipped with a motor driven rake mechanism to collect settled sludge and move it to a central discharge point.

SEDIMENTATION BASIN: Where the thickest and greatest concentration of sludge will be found. Twice a year sedimentation tanks should be drained and cleaned if the sludge buildup interferes with the treatment process.

SEDIMENTATION: The process of suspended solid particles settling out (going to the bottom of the vessel) in water.

SEDIMENT: Grains of soil, sand, gravel, or rock deposited by and generated by water movement.

SENSOR: A float and cable system are commonly found instruments that may be used as a sensor to control the level of liquid in a tank or basin.

SEPTIC: Condition characterized by bacterial decomposition under anaerobic conditions.

SETTLEABILITY: The tendency of suspended solids to settle.

SETTLEABLE SOLIDS: That portion of suspended solids which are of a sufficient size and weight to settle to the bottom of an Imhoff cone in one hour.

SETTLED SLUDGE VOLUME: Volume of settled sludge measured at predetermined time increments for use in process control calculations.

SETTLED SOLIDS: Solids that have been removed from the raw water by the coagulation and settling processes.

SEWAGE: Liquid or waterborne wastes polluted or fouled from households, commercial or industrial operations, along with any surface water, storm water or groundwater infiltration.

SEWER GAS: A gas mixture produced by anaerobic decomposition of organic matter usually containing high percentages of methane and hydrogen sulfide.

SHEATHED: Filamentous, gram-negative, aerobic; "swarmer" (colonizing) cells form and break out of a sheath; sometimes coated with metals from environment.

SHOCK: Also known as superchlorination or break point chlorination. Ridding a water of organic waste through oxidization by the addition of significant quantities of a halogen.

SHOCK LOAD: A sudden hydraulic or organic load to a treatment plant, also descriptive of a change in the material being treated.

SHORT-CIRCUITING: Short Circuiting is a condition that occurs in tanks or basins when some of the water travels faster than the rest of the flowing water. This is usually undesirable since it may result in shorter contact, reaction or settling times in comparison with the presumed detention times.

SHOULD: This action, activity, or procedural step is suggested but not required.

SINGLE PHASE POWER: The type of power used for lighting systems, small motors, appliances, portable power tools and in homes.

SLOP OIL: Separator skimmings and tramp oil generated during refinery startup, shutdown or abnormal operation.

SLUDGE: Accumulated and concentrated solids generated within a treatment process that have not undergone a stabilization process.

SLUDGE BASINS: After cleaning sludge basins and before returning the tanks into service the tanks should be inspected, repaired if necessary, and disinfected.

SLUDGE BLANKET: The accumulated sludge suspended in a clarifier or other enclosed body of water.

SLUDGE DEWATERING: The removal of a portion or majority of the water contained in sludge by means of a filter press, centrifuge or other mechanism.

SLUDGE DRYING BED: A closed area consisting of sand or other porous material upon which sludge is dewatered by gravity drainage and evaporation.

SLUDGE REDUCTION: Organic polymers are used to reduce the quantity of sludge. If a plant produces a large volume of sludge, the sludge could be dewatered, thickened, or conditioned to decrease the volume of sludge. Turbidity of source water, dosage, and type of coagulant used are the most important factors which determine the amount of sludge produced in a treatment of water.

SLURRY: A mixture of a solid and a liquid that facilitates the transfer of the solid into a treatment solution.

SOC: A common way for a synthetic organic chemical such as dioxin to be introduced to a surface water supply is from an industrial discharge, agricultural drainage, or a spill.

SODA ASH: Chemical used to raise pH and total alkalinity (sodium carbonate)

SODIUM BICARBONATE: Commonly used to increase alkalinity of water and stabilize pH.

SODIUM BISULFATE: Chemical used to lower pH and total alkalinity (dry acid).

SODIUM HYDROXIDE: Also known as caustic soda, a by-product chlorine generation and often used to raise pH.

SOFTENING WATER: When the water has a low alkalinity it is advantageous to use soda ash instead of caustic soda for softening water.

SOFTENING: The process that removes the ions which cause hardness in water.

SOLID, LIQUID AND VAPOR: 3 forms of matter.

SOLID WASTE: Garbage, refuse, sludge and other discarded material resulting from community activities or commercial or industrial operations.

SOLUBILITY: The amount of a substance that can dissolve in a solution under a given set of conditions.

SPADNS: The lab reagent called SPADNS solution is used in performing the Fluoride test.

SPIKING SUSPENSION: Diluted stock suspension containing the organism(s) of interest at a concentration appropriate for spiking samples.

SPIRILLUM: Spiral-shaped, gram-negative, aerobic; include *Bdellovibrio*, predatory on other bacteria.

SPIROCHETE: Spiral-shaped, gram-negative, mostly anaerobic; common in moist environments, from mammalian gums to coastal mudflats; complex internal structures convey rapid movement; include *Treponemapallidum*, cause of syphilis.

SPOROZOITE: A motile, infective stage of certain protozoans; e.g., *Cryptosporidium*. There are four sporozoites in each *Cryptosporidium* oocyst, and they are generally banana-shaped.

SPRAY BOTTLE OF AMMONIA: An operator should use ammonia to test for a chlorine leak around a valve or pipe. You will see white smoke if there is a leak.

SPRING PRESSURE: Is what maintains contact between the two surfaces of a mechanical seal.

STABILIZATION POND: A large shallow basin used for wastewater treatment by natural processes involving the use of algae and bacteria to accomplish biological oxidation of organic matter.

STERILIZED GLASSWARE: The only type of glassware that should be used in testing for coliform bacteria.

STOCK SUSPENSION: A concentrated suspension containing the organism(s) of interest that is obtained from a source that will attest to the host source, purity, authenticity, and viability of the organism(s).

STUFFING BOX: That portion of the pump that houses the packing or mechanical seal.

SUBNATANT: Liquid remaining beneath the surface of floating solids.

SUCCESSION: Transition in the species composition of a biological community, often following ecological disturbance of the community; the establishment of a biological community in an area virtually barren of life.

SULFIDE: The term sulfide refers to several types of chemical compounds containing sulfur in its lowest oxidation number of -2. Formally, "sulfide" is the dianion, S^{2-} , which exists in strongly alkaline aqueous solutions formed from H_2S or alkali metal salts such as Li_2S , Na_2S , and K_2S . Sulfide is exceptionally basic and, with a $pK_a > 14$, it does not exist in appreciable concentrations even in highly alkaline water, being undetectable at $pH < \sim 15$ (8 M NaOH). Instead, sulfide combines with electrons in hydrogen to form HS^- , which is variously called hydrogen sulfide ion, hydrosulfide ion, sulfhydryl ion, or bisulfide ion. At still lower pH's (< 7), HS^- converts to H_2S , hydrogen sulfide. Thus, the exact sulfur species obtained upon dissolving sulfide salts depends on the pH of the final solution. Aqueous solutions of transition metals cations react with sulfide sources (H_2S , $NaSH$, Na_2S) to precipitate solid sulfides. Such inorganic sulfides typically have very low solubility in water and many are related to minerals. One famous example is the bright yellow species CdS or "cadmium yellow". The black tarnish formed on sterling silver is Ag_2S . Such species are sometimes referred to as salts. In fact, the bonding in transition metal sulfides is highly covalent, which gives rise to their semiconductor properties, which in turn is related to the practical applications of many sulfide materials.

SULFATE- AND SULFUR- REDUCING: Commonly rod-shaped, mostly gram-negative, anaerobic; include *Desulfovibrio*, ecologically important in marshes.

SULFUR- AND IRON- OXIDIZING: Commonly rod-shaped, frequently with polar flagella, gram-negative, mostly anaerobic; most live in neutral (nonacidic) environment.

SUPERNATANT: The liquid layer which forms above the sludge in a settling basin.

SURFACE SEAL: The upper portion of a wells construction where surface contaminants are adequately prevented from entering the well, normally consisting of surface casing and neat cement grout.

SURFACTANT: Surfactants reduce the surface tension of water by adsorbing at the liquid-gas interface. They also reduce the interfacial tension between oil and water by adsorbing at the liquid-liquid interface. Many surfactants can also assemble in the bulk solution into aggregates. Examples of such aggregates are vesicles and micelles. The concentration at which surfactants begin to form micelles is known as the critical micelle concentration or CMC. When micelles form in water, their tails form a core that can encapsulate an oil droplet, and their (ionic/polar) heads form an outer shell that maintains favorable contact with water. When surfactants assemble in oil, the aggregate is referred to as a reverse micelle. In a reverse micelle, the heads are in the core and the tails maintain favorable contact with oil. Surfactants are also often classified into four primary groups; anionic, cationic, non-ionic, and zwitterionic (dual charge).

SUSPENDED SOLIDS: Solids captured by filtration through a 0.45 micron filter membrane.

TCE, trichloroethylene: A solvent and degreaser used for many purposes; for example dry cleaning, it is a common groundwater contaminant. Trichloroethylene is a colorless liquid which is used as a solvent for cleaning metal parts. Drinking or breathing high levels of trichloroethylene may cause nervous system effects, liver and lung damage, abnormal heartbeat, coma, and possibly death. Trichloroethylene has been found in at least 852 of the 1,430 National Priorities List sites identified by the Environmental Protection Agency (EPA).

TDS-TOTAL DISSOLVED SOLIDS: An expression for the combined content of all inorganic and organic substances contained in a liquid which are present in a molecular, ionized or micro-granular (colloidal sol) suspended form. Generally, the operational definition is that the solids (often abbreviated TDS) must be small enough to survive filtration through a sieve size of two micrometers. Total dissolved solids are normally only discussed for freshwater systems, since salinity comprises some of the ions constituting the definition of TDS. The principal application of TDS is in the study of water quality for streams, rivers and lakes, although TDS is generally considered not as a primary pollutant (e.g. it is not deemed to be associated with health effects), but it is rather used as an indication of aesthetic characteristics of drinking water and as an aggregate indicator of presence of a broad array of chemical contaminants.

TDS: Ion exchange is an effective treatment process used to remove iron and manganese in a water supply. This process is ideal as long as the water does not contain a large amount of TDS. When determining the total dissolved solids, a sample should be filtered before being poured into an evaporating dish and dried. Demineralization may be necessary in a treatment process if the water has a very high value Total Dissolved Solids.

TELEMETERING: The use of a transmission line with remote signaling to monitor a pumping station or motors. Can be used to accomplish accurate and reliable remote monitoring and control over a long distribution system.

TEMPERATURE SAMPLE: This test should be performed immediately in the field, a grab sample.

TERTIARY TREATMENT: The use of physical, chemical, or biological means to improve secondary wastewater effluent quality.

THE RATE DECREASES: In general, when the temperature decreases, the chemical reaction rate decreases also.

THICKENING: A procedure used to increase the solids content of sludge by removing a portion of the liquid.

THICKENING, CONDITIONING AND DEWATERING: Common processes that are utilized to reduce the volume of sludge.

THOMAS MALTHUS: Formulated the concept that population growth proceeds at a geometric rate.

TIME FOR TURBIDITY BREAKTHROUGH AND MAXIMUM HEADLOSS: Are the two factors which determine whether or not a change in filter media size should be made.

TITRATION: A method of testing by adding a reagent of known strength to a water sample until a specific color change indicates the completion of the reaction.

TOTAL ALKALINITY: A measure of the acid-neutralizing capacity of water which indicates its buffering ability, i.e. measure of its resistance to a change in pH. Generally, the higher the total alkalinity, the greater the resistance to pH change.

TOTAL COLIFORM: Total coliform, fecal coliform, and E. coli are all indicators of drinking water quality. The total coliform group is a large collection of different kinds of bacteria. Fecal coliforms are types of total coliform that mostly exist in feces. E. coli is a sub-group of fecal coliform. When a water sample is sent to a lab, it is tested for total coliform. If total coliform is present, the sample will also be tested for either fecal coliform or E. coli, depending on the lab testing method.

TOTAL DISSOLVED SOLIDS (TDS): The accumulated total of all solids that might be dissolved in water. The weight per unit volume of all volatile and non-volatile solids dissolved in a water or wastewater after a sample has been filtered to remove colloidal and suspended solids.

TOTAL DYNAMIC HEAD: The pressure (psi) or equivalent feet of water, required for a pump to lift water to its point of storage overcoming elevation head, friction loss, line pressure, drawdown and pumping lift.

TOTAL SOLIDS: The sum of dissolved and suspended solids in a water or wastewater.

TOTAL SUSPENDED SOLIDS: The measure of particulate matter suspended in a sample of water or wastewater.

TOXIC: Capable of causing an adverse effect on biological tissue following physical contact or absorption.

TREATABILITY STUDY: A study in which a waste is subjected to a treatment process to determine treatment and/or to determine the treatment efficiency or optimal process conditions for treatment.

TRICHALOMETHANES (THM): Four separate compounds including chloroform, dichlorobromomethane, dibromochloromethane, and bromoform. The most common class of disinfection by-products created when chemical disinfectants react with organic matter in water during the disinfection process. See Disinfectant Byproducts.

TUBE SETTLERS: This modification of the conventional process contains many metal tubes that are placed in the sedimentation basin, or clarifier. These tubes are approximately 1 inch deep and 36 inches long, split-hexagonal shape and installed at an angle of 60 degrees or less. These tubes provide for a very large surface area upon which particles may settle as the water flows upward. The slope of the tubes facilitates gravity settling of the solids to the bottom of the basin, where they can be collected and removed. The large surface settling area also means that adequate clarification can be obtained with detention times of 15 minutes or less. As with conventional treatment, this sedimentation step is followed by filtration through mixed media.

TUBERCLES: The creation of this condition is of the most concern regarding corrosive water effects on a water system. Tubercles are formed due to joining dissimilar metals, causing electro-chemical reactions. Like iron to copper pipe. We have all seen these little rust mounds inside cast iron pipe.

TURBIDIMETER: Monitoring the filter effluent turbidity on a continuous basis with an in-line instrument is a recommended practice. Turbidimeter is best suited to perform this measurement.

TURBIDITY: A measure of the cloudiness of water caused by suspended particles. A qualitative measurement of water clarity which results from suspended matter that scatters or otherwise interferes with the passage of light through the water.

ULTRAFILTRATION: A low pressure membrane filtration process which separates solutes up to 0.1 micron size range.

UNDER PRESSURE IN STEEL CONTAINERS: After chlorine gas is manufactured, it is primarily transported in steel containers.

UP FLOW CLARIFIER: Clarifier where flocculated water flows upward through a sludge blanket to obtain floc removal by contact with flocculated solids in the blanket.

U.S. ENVIRONMENTAL PROTECTION AGENCY: In the United States, this agency responsible for setting drinking water standards and for ensuring their enforcement. This agency sets federal regulations which all state and local agencies must enforce.

VANE: That portion of an impeller that throws the water toward the volute.

VAPOR: The gaseous phase of a material that is in the solid or liquid state at standard temperature and pressure.

VARIABLE DISPLACEMENT PUMP: A pump that will produce different volumes of water dependent on the pressure head against it.

VELOCITY HEAD: The vertical distance a liquid must fall to acquire the velocity with which it flows through the piping system. For a given quantity of flow, the velocity head will vary indirectly as the pipe diameter varies.

VENTURI: If water flows through a pipeline at a high velocity, the pressure in the pipeline is reduced. Velocities can be increased to a point that a partial vacuum is created.

VERTICAL TURBINE: A type of variable displacement pump in which the motor or drive head is mounted on the wellhead and rotates a drive shaft connected to the pump impellers.

VIBRIO: Rod- or comma-shaped, gram-negative, aerobic; commonly with a single flagellum; include *Vibrio cholerae*, cause of cholera, and luminescent forms symbiotic with deep-water fishes and squids.

VIRUSES: Very small disease-causing microorganisms that are too small to be seen even with microscopes. Viruses cannot multiply or produce disease outside of a living cell.

VITRIFICATION: Vitrification is a process of converting a material into a glass-like amorphous solid that is free from any crystalline structure, either by the quick removal or addition of heat, or by mixing with an additive. Solidification of a vitreous solid occurs at the glass transition temperature (which is lower than melting temperature, T_m , due to supercooling). When the starting material is solid, vitrification usually involves heating the substances to very high temperatures. Many ceramics are produced in such a manner. Vitrification may also occur naturally when lightning strikes sand, where the extreme and immediate heat can create hollow, branching rootlike structures of glass, called fulgurite. When applied to whiteware ceramics, vitreous means the material has an extremely low permeability to liquids, often but not always water, when determined by a specified test regime. The microstructure of whiteware ceramics frequently contain both amorphous and crystalline phases.

VOLATILE: A substance that evaporates or vaporizes at a relatively low temperature.

VOLATILE ORGANIC COMPOUNDS (VOCs): Solvents used as degreasers or cleaning agents. Improper disposal of VOCs can lead to contamination of natural waters. VOCs tend to evaporate very easily. This characteristic gives VOCs very distinct chemical odors like gasoline, kerosene, lighter fluid, or dry cleaning fluid. Some VOCs are suspected cancer-causing agents. Volatile organic compounds (VOCs) are organic chemical compounds that have high enough vapor pressures under normal conditions to significantly vaporize and enter the atmosphere. A wide range of carbon-based molecules, such as aldehydes, ketones, and other light hydrocarbons are VOCs. The term often is used in a legal or regulatory context and in such cases the precise definition is a matter of law. These definitions can be contradictory and may contain "loopholes"; e.g. exceptions, exemptions, and exclusions. The United States Environmental Protection Agency defines a VOC as any organic compound that participates in a photoreaction; others believe this definition is very broad and vague as organics that are not volatile in the sense that they vaporize under normal conditions can be considered volatile by this EPA definition. The term may refer both to well characterized organic compounds and to mixtures of variable composition.

VOID: An opening, gap, or space within rock or sedimentary formations formed at the time of origin or deposition.

VOLTAGE: Voltage (sometimes also called electric or electrical tension) is the difference of electrical potential between two points of an electrical or electronic circuit, expressed in volts.[1] It measures the potential energy of an electric field to cause an electric current in an electrical conductor. Depending on the difference of electrical potential it is called extra low voltage, low voltage, high voltage or extra high voltage. Specifically Voltage is equal to energy per unit charge.

VOLUTE: The spiral-shaped casing surrounding a pump impeller that collects the liquid discharge by the impeller.

VORTICELLA: Vorticella is a genus of protozoa, with over 100 known species. They are stalked inverted bell-shaped ciliates, placed among the peritrichs. Each cell has a separate stalk anchored onto the substrate, which contains a contractile fibril called a myoneme. When stimulated this shortens, causing the stalk to coil like a spring. Reproduction is by budding, where the cell undergoes longitudinal fission and only one daughter keeps the stalk. Vorticella mainly lives in freshwater ponds and streams - generally anywhere protists are plentiful. Other genera such as Carchesium resemble Vorticella but are branched or colonial.

VORTEX: The helical swirling of water moving towards a pump.

VIRUSES: are very small disease-causing microorganisms that are too small to be seen even with microscopes. Viruses cannot multiply or produce disease outside of a living cell.

VULNERABILITY ASSESSMENT: An evaluation of drinking water source quality and its vulnerability to contamination by pathogens and toxic chemicals.

WAIVERS: Monitoring waivers for nitrate and nitrite are prohibited.

WASTE ACTIVATED SLUDGE: Excess activated sludge that is discharged from an activated sludge treatment process.

WASTEWATER: Liquid or waterborne wastes polluted or fouled from households, commercial or industrial operations, along with any surface water, storm water or groundwater infiltration.

WATER HAMMER: A surge in a pipeline resulting from the rapid increase or decrease in water flow. Water hammer exerts tremendous force on a system and can be highly destructive.

WATER QUALITY CRITERIA: Comprised of both numeric and narrative criteria. Numeric criteria are scientifically derived ambient concentrations developed by EPA or States for various pollutants of concern to protect human health and aquatic life. Narrative criteria are statements that describe the desired water quality goal.

WATER QUALITY STANDARD: A statute or regulation that consists of the beneficial designated use or uses of a waterbody, the numeric and narrative water quality criteria that are necessary to protect the use or uses of that particular waterbody, and an antidegradation statement.

WATERBORNE DISEASE: A disease, caused by a virus, bacterium, protozoan, or other microorganism, capable of being transmitted by water (e.g., typhoid fever, cholera, amoebic dysentery, gastroenteritis).

WATER RECLAMATION: The restoration of wastewater to a state that will allow its beneficial reuse.

WHOLE EFFLUENT TOXICITY: The total toxic effect of an effluent measured directly with a toxicity test.

WPCF: Water Pollution Control Facility

WTP: Water Treatment Plant

WWTP: Wastewater Treatment Plant

ZERO DISCHARGE: A facility that discharges no liquid effluent to the environment.



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Aluminum, Copper, And Nonferrous Metals Forming And Metal Powders Pretreatment Standards: A Guidance Manual	December 1989	800-B-89-001	PB91-145441	W119
CERCLA Site Discharges to POTWs Guidance Manual	August 1990	540-G-90-005	PB90-274531	W150
Control Authority Pretreatment Audit Checklist and Instructions	May 1992	-- -- --		
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Guidance For Developing Control Authority Enforcement Response Plans	September 1989	--	PB90-185083/AS	--
Guidance for Reporting and Evaluating POTW Noncompliance with Pretreatment Implementation Requirements	September 1987	--	PB95-157764	W304
Guidance Manual For Battery Manufacturing Pretreatment Standards	August 1987	440-1-87-014	PB92-117951	W195
Guidance Manual for Electroplating and Metal Finishing Pretreatment Standard	February 1984	440-1-84-091-G	PB87-192597	W118
Guidance Manual For Implementing Total Toxic Organics (TTO) Pretreatment Standards	September 1985	440-1-85-009-T	PB93-167005	W339
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Guidance Manual for POTWs to Calculate the Economic Benefit of Noncompliance	September 1990	833-B-93-007	-- --	
Guidance Manual for Preparation and Review of Removal Credit Applications	July 1985	833-B-85-200	-- --	
Guidance Manual for Preventing Interference at POTWs	September 1987	833-B-87-201	PB92-117969	W106
Guidance Manual for Pulp, Paper, and Paperboard and Builders' Paper and Board Mills Pretreatment Standards	July 1984	--	PB92-231638	W196
Guidance Manual for the Identification of Hazardous Wastes Delivered to Publicly Owned Treatment Works by Truck, Rail, or Dedicated Pipe	June 1987	--	PB92-149251	W202
Guidance Manual for the Use of Production-Based Pretreatment Standards and the Combined Wastestream Formula	September 1985	833-B-85-201	PB92-232024	U095
Guidance Manual on the Development and Implementation of Local Discharge Limitations Under the Pretreatment Program	December 1987	833-B-87-202	PB92-129188	W107
Guidance on Evaluation, Resolution, and Documentation of Analytical Problems Associated with Compliance Monitoring	June 1993	821-B-93-001	-- --	
Guidance to Protect POTW Workers From Toxic And Reactive Gases And Vapors	June 1992	812-B-92-001	PB92-173236	W115
Guides to Pollution Prevention: Municipal Pretreatment Programs	October 1993	625-R-93-006	-- --	
Industrial User Inspection and Sampling Manual For POTWs	April 1994	831-B-94-001	PB94-170271	W305
Industrial User Permitting Guidance Manual	September 1989	833-B-89-001	PB92-123017	W109

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1996 Clean Water Needs Survey Report to Congress: Assessment of Needs for Publicly Owned Wastewater Treatment Facilities, Correction of Combined Sewer Overflows, and Management of Stormwater and Nonpoint Source Pollution in the United States.

Other Guidance Documents that can help you

Guidance Manual For Implementing Total Toxic Organics (TTO) Pretreatment Standards

Guidance Manual for Preparation and Review of Removal Credit Applications

Guidance Manual for Preventing Interference at POTWs

Guidance Manual for the Identification of Hazardous Wastes Delivered to Publicly Owned Treatment Works by Truck, Rail, or Dedicated Pipe

Guidance Manual for the Use of Production-Based Pretreatment Standards and the Combined Wastestream Formula

Guidance Manual on the Development and Implementation of Local Discharge Limitations Under the Pretreatment Program

Guidance to Protect POTW Workers From Toxic And Reactive Gases And Vapors

Prelim User's Guide, Documentation for the EPA Computer Program/Model for Developing Local Limits for Industrial Pretreatment Programs at Publicly Owned Treatment Works

Supplemental Manual On the Development And Implementation of Local Discharge Limitations Under The Pretreatment Program: Residential and Commercial

Toxic Pollutant Loadings And POTW Removal Efficiency Estimation

CERCLA Site Discharges to POTWs Guidance Manual

Control of Slug Loadings To POTWs: Guidance Manual

Guidance For Developing Control Authority Enforcement Response Plans

Guidance Manual for POTWs to Calculate the Economic Benefit of Noncompliance

Industrial User Inspection and Sampling Manual For POTWs

Industrial User Permitting Guidance Manual

Model Pretreatment Ordinance

Multijurisdictional Pretreatment Programs: Guidance Manual

NPDES Compliance Inspection Manual

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