

CEU Training Course

8 Contact hours, 8 PDHs



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You can obtain a printed version from TLC for an additional \$49.95 plus shipping charges.

Important Information about this Manual

Disclaimer

This manual has been prepared to assist employees in the general awareness of the water treatment and groundwater production system, complex water treatment ideas, dangerous laboratory techniques, water regulatory sampling and dealing with often-complex procedures and requirements for safely handling hazardous and toxic materials. 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 training manual will cover general laws, regulations, required procedures and work rules relating to water treatment and 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 and hyperlinks is provided to assist in obtaining the most up-to-date information on various subjects. You can find these on our website or in this manual.

This manual is a guidance document for employees who are involved with water distribution, 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) rules and regulations.

This course manual will provide general guidance and should not be used as a preliminary basis for developing general water sampling plans or water treatment safety plans or procedures. This document is not a detailed water textbook or a comprehensive source book on water/safety rules and regulations.

Technical Learning College makes no warranty, guarantee or representation as to the absolute correctness or appropriateness of the information in this manual and assumes no responsibility in connection with the implementation of this information.

It cannot be assumed that this manual contains all measures and concepts required for specific conditions or circumstances. This document should be used for guidance and is not considered a legal document. Individuals who are responsible for water distribution, production and/or sampling and the health and safety of workers at hazardous waste sites should obtain and comply with the most recent federal, state, and local regulations relevant to these sites and are urged to consult with OSHA, EPA and other appropriate federal, state and local agencies.

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Water Treatment Process Control CEU Training Course Description

Introduction

Review of water treatment and filter operation, starting with hydraulic fundamentals and advancing to the rules of the Safe Drinking Water Act. The challenges faced in treating drinking water are to simultaneously meet compliance requirements while maintaining operational and maintenance conditions throughout the treatment process. Individuals involved with water treatment process control are required not only to manage quality changes in the plant but communicate those changes with other parties involved, such as plant management and staff. The objectives of this short CEU course is to provide a better understanding of the Safe Drinking Water Act regulations, terminology associated with the regulations, water quality parameters, how quality impacts the rules and processes and the individual feed point criteria.

Prerequisites: None

Course Procedures for Registration and Support

All of Technical Learning College 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.

Instructions for Written Assignments

The ***Water Treatment Process Control*** CEU Training course uses a multiple-choice answer key, Scantron, or equivalent answer sheet. The students must use a number two pencil, make dark marks, and erase completely to change an answer. You can find an extra copy of the assignment and complete Student Support on the Website under the Assignment Page.

Feedback Mechanism (examination procedures)

Each student will receive a feedback form as part of their study packet. You will be able to 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 ***Water Treatment Process Control*** CEU Training course comes complete with a summary of the SDWA's rules and Regulations. You will be able to find the entire law on line at www.epa.gov. No other materials are needed.

Recordkeeping and Reporting Practices

TLC will keep all student records for a minimum of seven years. It is your responsibility to give the completion certificate to the appropriate agencies. We will send the required information to Texas, Indiana and Pennsylvania for your certificate renewals.

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.

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 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.



We have taught this course to approximately ten thousand students in a conventional classroom setting. You are welcome to do the correspondence course or attend a TLC class. This class was in Louisiana following the Wilma hurricane that destroyed the water treatment system.



The two primary teaching professors for the west coast. Melissa Durbin as seen in action in the top photograph. Jeff Durbin in the bottom photograph.



Waterborne Diseases

Name	Causative organism	Source of organism	Disease
Viral gastroenteritis	Rotavirus (mostly in young children)	Human feces	Diarrhea or vomiting
Norwalk Agent	Noroviruses (genus <i>Norovirus</i> , family <i>Caliciviridae</i>) * ¹	Human feces; also, shellfish; lives in polluted waters	Diarrhea and vomiting
Salmonellosis	Salmonella (bacterium)	Animal or human feces	Diarrhea or vomiting
Gastroenteritis <i>Escherichia coli</i>	-- <i>E. coli</i> O1 57:H7 (bacterium): Other <i>E. coli</i> organisms:	Human feces	Symptoms vary with type caused
Typhoid	Salmonella typhi (bacterium)	Human feces, urine	Inflamed intestine, enlarged spleen, high temperature-sometimes fatal
Shigellosis	Shigella (bacterium)	Human feces	Diarrhea
Cholera	Vibrio choleras (bacterium)	Human feces; also, shellfish; lives in many coastal waters	Vomiting, severe diarrhea, rapid dehydration, mineral loss-high mortality
Hepatitis A	Hepatitis A virus	Human feces; shellfish grown in polluted waters	Yellowed skin, enlarged liver, fever, vomiting, weight loss, abdominal pain-low mortality, lasts up to four months
Amebiasis	Entamoeba histolytica (protozoan)	Human feces	Mild diarrhea, dysentery, extra intestinal infection
Giardiasis	Giardia lamblia (protozoan)	Animal or human feces	Diarrhea, cramps, nausea, and general weakness — lasts one week to months
Cryptosporidiosis	Cryptosporidium parvum	Animal or human feces	Diarrhea, stomach pain — lasts (protozoan) days to weeks

Notes:

*1 <http://www.cdc.gov/ncidod/dvrd/revb/gastro/norovirus.htm>
<http://www.cdc.gov/mmwr/preview/mmwrhtml/rr5009a1.htm>

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Water treatment plant operators' backwash filters use control panels.

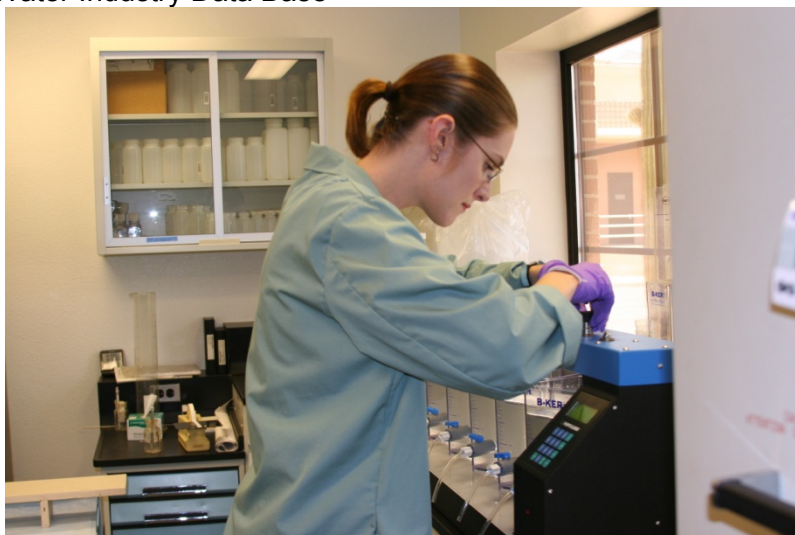


The Process Control Specialist will make visual observations of plant conditions throughout the day and monitor SCADA and laboratory results.

LIST OF COMMONLY FOUND WATER TREATMENT ACRONYMS

AA	Atomic Absorption
AOP	Advance Oxidation Process
ASTM	American Society for Testing and Materials
AWWA	American Water Works Association
AWWARF	American Water Works Association Research Foundation
BAT	Best Available Technology
BDCAA	Bromodichloroacetic Acid
CDBAA	Chlorodibromoacetic Acid
CFR	Code of Federal Regulations
CT	Contact Time
CWS	Community Water System
DAF	Dissolved Air Flotation
DBP	Disinfection Byproduct
DBPFP	Disinfection Byproduct Formation Potential
DBPR	Disinfection Byproduct Rule
DCAA	Dichloroacetic acid
DCAN	Dichloroacetoneitrile
DI	Deionized
DOC	Dissolved Organic Carbon
EBCT	Empty Bed Contact Time
EC	Enhanced Coagulation
ECD	Electron Capture Detector
EDTA	Ethylenediamine tetraacetic acid
IESWTR	Interim Enhanced Surface Water Treatment Rule
EPA	Environmental Protection Agency
ES	Enhanced Softening
FACA	Federal Advisory Committee Act
GAC	Granulated Activated Carbon
GC	Gas Chromatograph
HAA	Haloacetic Acid
HAA5	Haloacetic Acids, group of 5: mono-, di-, and trichloroacetic acids; and mono- and dibromoacetic acids
HAAFP	Haloacetic Acid Formation Potential
HAN	Haloacetoneitrile
HANFP	Haloacetoneitrile Formation Potential
ICP	Inductively Coupled Plasma
ICR	Information Collection Rule
IESWTR	Interim Enhanced Surface Water Treatment Rule
LT2ESWTR	Long Term 2 Enhanced Surface Water Treatment Rule
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
MF	Microfiltration
MRDL	Maximum Residual Disinfectant Level
MRDLG	Maximum Residual Disinfectant Level Goal
MRL	Minimum Reporting Level
MTBE	Methyl-t-butyl ether
MW	Molecular Weight
MWCO	Molecular Weight Cutoff

NF	Nanofiltration
NIST	National Institute of Sciences and Technology
NOM	Natural Organic Matter
NPDWR	National Primary Drinking Water Regulation
NSF	National Sanitation Foundation
NTNCWS	Non-transient, Non-community Water System
PAC	Powdered Activated Carbon
PACl	Polyaluminum Chloride
PE	Performance Evaluation
PODR	Point of Diminishing Return
PQL	Practical Quantitation Limit
RAA	Running Annual Average
RO	Reverse Osmosis
SDS	Simulated Distribution System
SDWA	Safe Drinking Water Act
SMCL	Secondary Maximum Contaminant Level
SOC	Synthetic Organic Chemical
SUVA	Specific Ultraviolet Absorption
TBAA	Tribromacetic Acid
TCAA	Trichloroacetic acid
THM	Trihalomethane
THMFP	Trichloromethane Formation Potential
TMSD	Trimethylsilyl Diazomethane
TNCWS	Transient Non-community Water System
TOC	Total Organic Carbon
TOX	Total Organic Halides
TOXFP	Total Organic Halides Formation Potential
TTHM	Total Trihalomethanes
UF	Ultrafiltration
UFC	Uniform Formation Condition
UV	Ultraviolet
UV-254	Ultraviolet absorbance at a wavelength of 254 nm
WIDB	Water Industry Data Base



Preparing the jar test to simulate plant conditions.

National Drinking Water Regulations

The Act instructs the EPA on how to select contaminants for regulation and specifies how EPA must establish national primary drinking water regulations once a contaminant has been selected (Section 1412). As of late 1996, the EPA had promulgated 84 drinking water regulations.

Contaminant Selection

P.L. 104-182 establishes a new process for the EPA to select contaminants for regulatory consideration based on occurrence, health effects, and meaningful opportunity for health risk reduction. By February 1998 and every 5 years thereafter, the EPA must publish a list of contaminants that may warrant regulation. Starting in 2001, and every 5 years thereafter, the EPA must determine whether or not to regulate at least 5 of the listed contaminants. The Act directs the EPA to evaluate contaminants that present the greatest health concern and to regulate contaminants that occur at concentration levels and frequencies of public health concern. The law also includes a schedule for EPA to complete regulations for disinfectants and disinfection byproducts (**D/DBPs**) and ***Cryptosporidium*** (a waterborne pathogen).

Standard Setting

Developing national drinking water regulations is a two-part process. For each contaminant that the EPA has determined merits regulation, the EPA must set a non-enforceable maximum contaminant level goal (**MCLG**) at a level at which no known or anticipated adverse health effects occur and which allows an adequate margin of safety. The EPA must then set an enforceable standard, and a maximum contaminant level (**MCL**), as close to the MCLG as is "**feasible**" using the best technology, treatment techniques, or other means available (taking costs into consideration).

Standards are generally based on technologies that are affordable for large communities; however, under P.L. 104-182, each regulation establishing an MCL must list any technologies, treatment techniques or other means that comply with the MCL and that are affordable for three categories of small public water systems. The 1996 Amendments authorize the EPA to set a standard at other than the feasible level if the feasible level would lead to an increase in health risks by increasing the concentration of other contaminants or by interfering with the treatment processes used to comply with other SDWA regulations. In such cases, the standard or treatment techniques must minimize the overall health risk. Also, when proposing a regulation, the EPA must now publish a determination as to whether or not the benefits of the standard justify the costs. If the EPA determines that the benefits do not justify the costs, the EPA may, with certain exceptions, promulgate a standard that maximizes health risk reduction benefits at a cost that is justified by the benefits.

Risk Assessment

P.L. 104-182 adds risk assessment and communication provisions to SDWA. When developing regulations, the EPA is now required to: (1) use the best available, peer-reviewed science and supporting studies and data; and (2) make publicly available a risk assessment document that discusses estimated risks, uncertainties, and studies used in the assessment. When proposing drinking water regulations, the EPA must publish a health risk reduction and cost analysis. The law permits the EPA to promulgate an interim standard without first preparing a benefit-cost analysis or making a determination as to whether the benefits of a regulation would justify the costs if the EPA determines that a contaminant presents an urgent threat to public health.

New regulations generally become effective 3 years after promulgation. Up to 2 additional years may be allowed if the EPA (or a state in the case of an individual system) determines the time is needed for capital improvements. Section 1412 includes specific provisions for arsenic, sulfate and radon. The law authorizes states to grant Systems variances from a regulation if raw water quality prevents meeting the standards despite application of best technology (Section 1415). A new provision authorizes small system variances based on best affordable technology. States may grant these variances to systems serving 3,300 or fewer persons if the system cannot afford to comply (through treatment, an alternative water source, or restructuring) and the variance ensures adequate protection of public health; states may grant variances to systems serving between 3,300 and 10,000 persons with EPA approval. To receive a small system variance, the system must install a variance technology identified by the EPA. The variance technology need not meet the MCL, but must protect public health. By August 1998, the EPA must identify variance technologies for existing regulations. Variances are not available for microbial contaminants. The Act also provides for exemptions if a regulation cannot be met for other compelling reasons (including costs) and if the system was in operation before the effective date of a standard or treatment requirement (Section 1416). An exemption is intended to give a public water system more time to comply with a regulation and can be issued only if it will not result in an unreasonable health risk. Small systems may receive exemptions for up to 9 years.

State Primacy

The primary enforcement responsibility for public water systems lies with the states, provided they adopt regulations as stringent as the national requirements, adopt authority for administrative penalties, develop adequate procedures for enforcement, maintain records, and create a plan for providing emergency water supplies (Section 1413). Currently, 55 of 57 states and territories have primacy authority. P.L. 104-182 authorizes \$100 million annually for the EPA to make grants to states to carry out the public water system supervision program. States may also use a portion of their SRF grant for this purpose (Section 1443).

Whenever the EPA finds that a public water system in a state with primary enforcement authority does not comply with regulations, the Agency must notify the state and the system and provide assistance to bring the system into compliance. If the state fails to commence enforcement action within 30 days after the notification, the EPA is authorized to issue an administrative order or commence a civil action.

Non-primacy State

In a non-primacy state, the EPA must notify an elected local official (if any has jurisdiction over the water system) before commencing an enforcement action against the system (Section 1414). Primacy states may establish alternative monitoring requirements to provide interim monitoring relief for systems serving 10,000 or fewer persons for most contaminants, if a contaminant is not detected in the first quarterly sample. States with approved source water protection programs may adopt alternative monitoring requirements to provide permanent monitoring relief to qualified systems for chemical contaminants (Section 1418).

P.L. 104-182 requires states to adopt programs for training and certifying operators of community and nontransient noncommunity systems. The EPA must publish guidelines specifying minimum standards for operator certification by February 1999. Two years thereafter, the EPA must withhold 20% of a state's SRF grant unless the state has an operator certification program (Section 1419). States are also required to establish capacity development programs based on EPA guidance.

State programs must include: 1) legal authority to ensure that new systems have the technical, financial, and managerial capacity to meet SDWA requirements; and 2) a strategy to assist existing systems that are experiencing difficulties to come into compliance. Beginning in FY2001, EPA is required to withhold a portion of SRF grants from states that do not have compliance development strategies (Section 1420).

Underground Injection Control

Another provision of the Act requires the EPA to promulgate regulations for state underground injection control (**UIC**) programs to protect underground sources of drinking water. These regulations contain minimum requirements for the underground injection of wastes in five well classes to protect underground sources of drinking water and to require that a state prohibit, by December 1977, any underground injection that was not authorized by state permit (Section 1421).

Ground Water Protection Grant Programs

The Act contains three additional ground water protection programs. Added in 1986, Section 1427 established procedures for demonstration programs to develop, implement, and assess critical aquifer protection areas already designated by the Administrator as sole source aquifers. Section 1428, also added in 1986, and established an elective state program for protecting wellhead areas around public water system wells.

If a state established a wellhead protection program by 1989, and the EPA approved the state's program, then the EPA may award grants covering between 50% and 90% of the costs of implementing the program. Section 1429, added by P.L. 104-182, authorizes EPA to make 50% grants to states to develop programs to ensure coordinated and comprehensive protection of ground water within the states. Appropriations for these three programs and for LYIC state program grants are authorized starting FY2003.

Source Water Protection Programs

P.L. 104-182 broadens the pollution prevention focus of the Act to embrace surface water, as well as ground water protection. New Section 1453 directs the EPA to publish guidance for states to implement source water assessment programs that delineate boundaries of assessment areas from which systems receive their water, and identify the origins of contaminants in delineated areas to determine systems' susceptibility to contamination. States with approved assessment programs may adopt alternative monitoring requirements to provide systems with monitoring relief under Section 1418.

New Section 1454 authorizes a source water petition program based on voluntary partnerships between state and local governments. States may establish a program under which a community water system or local government may submit a source water quality partnership petition to the state requesting assistance in developing a voluntary partnership to: (1) reduce the presence of contaminants in drinking water; (2) receive financial or technical assistance; and (3) develop a long-term source water protection strategy. This section authorizes \$5 million each year for grants to states to support petition programs.

Also, states may use up to 10% of their annual SRF capitalization grant for the source water assessment activities or for the petition program.

State Revolving Funds

Section 1452, added by P.L. 104-182, authorizes a State Revolving Loan Fund (SRF) program to help systems finance improvements needed to comply with drinking water regulations. The law authorizes the EPA to make grants to states to capitalize SDWA SRFs, which states then use to make loans to public water systems. States must match 20% of the federal grant.

Grants will be allotted to states using the formula for distributing state PWSS grants through FY1997; then, grants will be allotted based on a needs survey. Each state will receive at least 1% of funds. The District of Columbia will receive 1% of funds as well. A state may transfer up to 33% of the grant to the Clean Water Act (CWA) SRF, or an equivalent amount from the CWA SRF to the SDWA SRF.

Drinking water SRFs may be used to provide loan and grant assistance for expenditures that the EPA has determined will facilitate compliance or significantly further the Act's health protection objectives. States must make available 15% of their annual allotment for loan assistance to systems that serve 10,000 or fewer persons. States may use up to 30% of their SRF grant to provide grants or forgive loan principle to help economically disadvantaged communities.



Also, states may use a portion of funds for technical assistance, source water protection and capacity development programs, and for operator certification.

Other Provisions

Public water systems must notify customers of violations with potential for serious health effects within 24 hours. Systems must also issue to customers annual reports on contaminants detected in their drinking water (Section 1414). Section 1417 requires any pipe, solder, or flux used in the installation or repair of public water systems or of plumbing in residential or nonresidential facilities providing drinking water to be "**lead free**" (as defined in the Act). As of August 1998, it will be unlawful to sell pipes, plumbing fittings or fixtures that are not "**lead free**" or to sell solder or flux that is not lead free (unless it is properly labeled); with the exception of pipes used in manufacturing or industrial processing. P.L. 104-182 sets limits on the amount of lead that may leach from new plumbing fixtures, and allows one year for a voluntary standard to be established before requiring EPA to take regulatory action. The Administrator has emergency powers to issue orders and commence civil action if a contaminant likely to enter a public drinking water supply system poses a substantial threat to public health and state or local officials have not taken adequate action (Section 1431).

If a chemical necessary for water treatment is not reasonably available, the Administrator can issue a "*certification of need*," in which case the President can order an allocation of the chemical to those needing it (Section 1441).

EPA is provided authority to conduct research, studies, and demonstrations related to the causes, treatment, control, and prevention of diseases resulting from contaminants in water.

The Agency is directed to provide technical assistance to the states and municipalities in administering their public water system regulatory responsibilities. The law authorizes annually, \$15 million for technical assistance to small systems and Indian Tribes, and \$25 million for health effects research (Section 1442). P.L. 104-182 authorizes additional appropriations for drinking water research, not to exceed \$26.6 million annually.

The Administrator may make grants to develop and demonstrate new technologies for providing safe drinking water and to investigate health implications involved in the reclamation/reuse of waste waters (Section 1444). Also, suppliers of water who may be subject to regulation under the Act are required to establish and maintain records, monitor, and provide any information that the Administrator requires to carry out the requirements of the Act (Section 1445).

The Administrator may also enter and inspect the property of water suppliers to enable him/her to carry out the purposes of the Act. Failure to comply with these provisions may result in criminal penalties. The Act established a National Drinking Water Advisory Council, composed of 15 members (with at least 2 representing rural systems), to advise, consult, and make recommendations to the Administrator on activities and policies derived from the Act (Section 1446).

National Security

Any federal agency having jurisdiction over federally owned and maintained public water systems must comply with all federal, state, and local drinking water requirements, as well as any underground injection control programs (Section 1447). The Act provides for waivers in the interest of national security. Procedures for judicial review are outlined (Section 1448), and provision is made for citizens' civil actions (Section 1449).

Citizen suits may be brought against any person or agency allegedly in violation of provisions of the Act, or against the Administrator for alleged failure to perform any action or duty which is not discretionary.

The EPA may use the new estrogenic substances screening program created in the Food Quality Protection Act of 1996 (P .L. 104-170) to provide for testing of substances that may be found in drinking water if the Administrator determines that a substantial population may be exposed to such substances (Section 1457).



Facilities must require identification from all who enter for security reasons.



Photographs of a water distribution water sampling truck.



Safe Drinking Water Act Terms

Community Water System (CWS) A public water system that serves at least 15 service connections used by year-round residents of the area served by the system or regularly serves at least 25 year-round residents.

Class V Underground Injection Control (UIC) Rule A rule under development covering wells not included in Class I, II, III or IV in which nonhazardous fluids are injected into or above underground sources of drinking water.

Contamination Source Inventory The process of identifying and inventorying contaminant sources within delineated source water protection areas through recording existing data, describing sources within the source water protection area, targeting likely sources for further investigation, collecting and interpreting new information on existing or potential sources through surveys, and verifying accuracy and reliability of the information gathered.

Cryptosporidium A protozoan associated with the disease cryptosporidiosis in humans. The disease can be transmitted through ingestion of drinking water, person-to-person contact, or other exposure routes. Cryptosporidiosis may cause acute diarrhea, abdominal pain, vomiting, and fever that lasts 1-2 weeks in healthy adults, but may be chronic or fatal in immuno-compromised people.

Drinking Water State Revolving Fund (DWSRF) Under section 1452 of the SDWA, the EPA awards capitalization grants to states to develop drinking water revolving loan funds to help finance drinking water system infrastructure improvements, source water protection, to enhance operations and management of drinking water systems, and other activities to encourage public water system compliance and protection of public health.

Exposure Contact between a person and a chemical. Exposures are calculated as the amount of chemical available for absorption by a person.

Giardia lamblia A protozoan, which can survive in water for 1 to 3 months, associated with the disease giardiasis. Ingestion of this protozoan in contaminated drinking water, exposure from person-to-person contact, and other exposure routes may cause giardiasis. The symptoms of this gastrointestinal disease may persist for weeks or months and include diarrhea, fatigue, and cramps.

Ground Water Disinfection Rule (GWDR) Under section 107 of the SDWA Amendments of 1996, the statute reads, ". . . the Administrator shall also promulgate national primary drinking water regulations requiring disinfection as a treatment technique for all public water systems, including surface water systems, and as necessary, ground water systems."

Maximum Contaminant Level (MCL) In the SDWA, an MCL is defined as "*the maximum permissible level of a contaminant in water which is delivered to any user of a public water system.*" MCLs are enforceable standards.

Maximum Contaminant Level Goal (MCLG) The maximum level of a contaminant in drinking water at which no known or anticipated adverse effect on the health effect of persons would occur, and which allows for an adequate margin of safety. MCLGs are non-enforceable public health goals.

Nephelometric Turbidity Units (NTU) A unit of measure used to describe the turbidity of water. Turbidity is the cloudiness in water.

Nitrates Inorganic compounds that can enter water supplies from fertilizer runoff and sanitary wastewater discharges. Nitrates in drinking water are associated with methemoglobinemia, or blue baby syndrome, which results from interferences in the blood's ability to carry oxygen.

Non-Community Water System (NCWS) A public water system that is not a community water system. There are two types of NCWSs: transient and non-transient.

Organics Chemical molecules that contain carbon and other elements such as hydrogen. Organic contaminants of concern to drinking water include chlorohydrocarbons, pesticides, and others.

Phase I Contaminants The Phase I Rule became effective on January 9, 1989. This rule, also called the Volatile Organic Chemical Rule, or VOC Rule, set water quality standards for 8 VOCs and required all community and Non-Transient, Non-Community water systems to monitor for, and if necessary, treat their supplies for these chemicals. The 8 VOCs regulated under this rule are: Benzene, Carbon Tetrachloride, para-dichlorobenzene, trichloroethylene, vinyl chloride, 1,1,2-trichloroethane, 1,1-dichloroethylene, and 1,2-dichloroethane.

Per capita Per person; generally used in expressions of water use, gallons per capita per day (gpcd).

Point-of-Use Water Treatment Refers to devices used in the home or office on a specific tap to provide additional drinking water treatment.

Point-of-Entry Water Treatment Refers to devices used in the home where water pipes enter to provide additional treatment of drinking water used throughout the home.

Primacy State State that has the responsibility for ensuring a law is implemented, and has the authority to enforce the law and related regulations. State has adopted rules at least as stringent as federal regulations and has been granted primary enforcement responsibility.

Radionuclides Elements that undergo a process of natural decay. As radionuclides decay, they emit radiation in the form of alpha or beta particles and gamma photons. Radiation can cause adverse health effects, such as cancer, so limits are placed on radionuclide concentrations in drinking water.

Risk The potential for harm to people exposed to chemicals. In order for there to be risk, there must be hazard and there must be exposure.

SDWA - The Safe Drinking Water Act The Safe Drinking Water Act was first passed in 1974 and established the basic requirements under which the nation's public water supplies were regulated. The US Environmental Protection Agency (**EPA**) is responsible for setting the national drinking water regulations while individual states are responsible for ensuring that public water systems under their jurisdiction are complying with the regulations. The SDWA was amended in 1986 and again in 1996.

Significant Potential Source of Contamination A facility or activity that stores, uses, or produces chemicals or elements, and that has the potential to release contaminants identified in a state program (contaminants with MCLs plus any others a state considers a health threat) within a source water protection area in an amount which could contribute significantly to the concentration of the contaminants in the source waters of the public water supply.

Sole Source Aquifer (SSA) Designation The surface area above a sole source aquifer and its recharge area.

Source Water Protection Area (SWPA) The area delineated by the state for a PWS or including numerous PWSs, whether the source is ground water or surface water or both, as part of the state SWPA approved by the EPA under section 1453 of the SDWA.

Sub-watershed A topographic boundary that is the perimeter of the catchment area of a tributary of a stream.

State Source Water Petition Program A state program implemented in accordance with the statutory language at section 1454 of the SDWA to establish local voluntary incentive-based partnerships for SWP and remediation.

State Management Plan (SMP) Program A state management plan under FIFRA required by the EPA to allow states (e.g. states, tribes and U.S. territories) the flexibility to design and implement approaches to manage the use of certain pesticides to protect ground water.

Surface Water Treatment Rule (SWTR) The rule specifies maximum contaminant level goals for *Giardia lamblia*, viruses and *Legionella*, and promulgated filtration and disinfection requirements for public water systems using surface water sources, or by ground water sources under the direct influence of surface water. The regulations also specify water quality, treatment, and watershed protection criteria under which filtration may be avoided.

Susceptibility Analysis An analysis to determine, with a clear understanding of where the significant potential sources of contamination are located, the susceptibility of the public water systems in the source water protection area to contamination from these sources. This analysis will assist the state in determining which potential sources of contamination are "significant."

To the Extent Practical States must inventory sources of contamination to the extent they have the technology and resources to complete an inventory for a Source Water Protection Area delineated as described in the guidance. All information sources may be used, particularly previous Federal and state inventories of sources.

Transient/Non-Transient, Non-Community Water Systems (T/NT, NCWS) Water systems that are non-community systems: transient systems serve 25 non-resident persons per day for 6 months or less per year. Transient non-community systems typically are restaurants, hotels, large stores, etc. Non-transient systems regularly serve at least 25 of the same non-resident persons per day for more than 6 months per year. These systems typically are schools, offices, churches, factories, etc.

Treatment Technique A specific treatment method required by the EPA to be used to control the level of a contaminant in drinking water. In specific cases where the EPA has determined it is not technically or economically feasible to establish an MCL, the EPA can instead specify a treatment technique. A treatment technique is an enforceable procedure or level of technical performance which public water systems must follow to ensure control of a contaminant.

Total Coliform Bacteria that are used as indicators of fecal contaminants in drinking water.

Toxicity The property of a chemical to harm people who come into contact with it.

Underground Injection Control (UIC) Program The program is designed to prevent underground injection which endangers drinking water sources. The program applies to injection well owners and operators on Federal facilities, Native American lands, and on all U.S. land and territories.

Watershed A topographic boundary area that is the perimeter of the catchment area of a stream.

Watershed Approach A watershed approach is a coordinating framework for environmental management that focuses public and private sector efforts to address the highest priority problems within hydrologically-defined geographic areas, taking into consideration both ground and surface water flow.

Watershed Area A topographic area that is within a line drawn connecting the highest points uphill of a drinking water intake, from which overland flow drains to the intake.

Wellhead Protection Area (WHPA) The surface and subsurface area surrounding a well or well field, supplying a PWS, through which contaminants are reasonably likely to move toward and reach such water well or well field.

42 USC Part A - SDWA Rule Definitions

TITLE 42 - THE PUBLIC HEALTH AND WELFARE
CHAPTER 6A - PUBLIC HEALTH SERVICE
SUBCHAPTER XII - SAFETY OF PUBLIC WATER SYSTEMS
Part A - Definitions

Part A - Definitions

42 USC Sec. 300f
01/05/99

TITLE 42 - THE PUBLIC HEALTH AND WELFARE
CHAPTER 6A - PUBLIC HEALTH SERVICE
SUBCHAPTER XII - SAFETY OF PUBLIC WATER SYSTEMS
Part A - Definitions

Sec. 300f. Definitions

For purposes of this subchapter:

- (1) The term "'primary drinking water regulation'" means a regulation which -
- (A) applies to public water systems;
 - (B) specifies contaminants which, in the judgment of the Administrator, may have any adverse effect on the health of persons;
 - (C) specifies for each such contaminant either -
 - (i) a maximum contaminant level, if, in the judgment of the Administrator, it is economically and technologically feasible to ascertain the level of such contaminant in water in public water systems, or
 - (ii) if, in the judgment of the Administrator, it is not economically or technologically feasible to so ascertain the level of such contaminant, each treatment technique known to the Administrator which leads to a reduction in the level of such contaminant sufficient to satisfy the requirements of section 300g-1 of this title; and
 - (D) contains criteria and procedures to assure a supply of drinking water which dependably complies with such maximum contaminant levels; including accepted methods for quality control and testing procedures to insure compliance with such levels and to insure proper operation and maintenance of the system, and requirements as to (i) the minimum quality of water which may be taken into the system and (ii) siting for new facilities for public water systems.

At any time after promulgation of a regulation referred to in this paragraph, the Administrator may add equally effective quality control and testing procedures by guidance published in the Federal Register. Such procedures shall be treated as an alternative for public water systems to the quality control and testing procedures listed in the regulation.

(2) The term ''secondary drinking water regulation'' which applies to public water systems and which specifies the maximum contaminant levels which, in the judgment of the Administrator, are requisite to protect the public welfare. Such regulations may apply to any contaminant in drinking water (A) which may adversely affect the odor or appearance of such water and consequently may cause a substantial number of the persons served by the public water system providing such water to discontinue its use, or (B) which may otherwise adversely affect the public welfare. Such regulations may vary accordingly to geographic and other circumstances.

(3) The term ''maximum contaminant level'' means the maximum permissible level of a contaminant in water which is delivered to any user of a public water system.

(4) Public water system. -

(A) In general. - The term ''public water system'' means a system for the provision to the public of water for human consumption through pipes or other constructed conveyances, if such system has at least fifteen service connections or regularly serves at least twenty-five individuals. Such term includes (i) any collection, treatment, storage, and distribution facilities under control of the operator of such system and used primarily in connection with such system, and (ii) any collection or pretreatment storage facilities not under such control which are used primarily in connection with such system.

(B) Connections. -

(i) In general. - For purposes of subparagraph (A), a connection to a system that delivers water by a constructed conveyance other than a pipe shall not be considered a connection, if -

(I) the water is used exclusively for purposes other than residential uses (consisting of drinking, bathing, and cooking, or other similar uses);

(II) the Administrator or the State (in the case of a State exercising primary enforcement responsibility for public water systems) determines that alternative water to achieve the equivalent level of public health protection provided by the applicable national primary drinking water regulation is provided for residential or similar uses for drinking and cooking; or

(III) the Administrator or the State (in the case of a State exercising primary enforcement responsibility for public water systems) determines that the water provided for residential or similar uses for drinking, cooking, and bathing is centrally treated or treated at the point of entry by the provider, a pass-through entity, or the user to achieve the equivalent level of protection provided by the applicable national primary drinking water regulations.

(ii) Irrigation districts. - An irrigation district in existence prior to May 18, 1994, that provides primarily agricultural service through a piped water system with only incidental residential or similar use shall not be considered to be a public water system if the system or the residential or similar users of the system comply with subclause (II) or (III) of clause (i).

(C) Transition period. - A water supplier that would be a

public water system only as a result of modifications made to this paragraph by the Safe Drinking Water Act Amendments of 1996 shall not be considered a public water system for purposes of the Act until the date that is two years after August 6, 1996. If a water supplier does not serve 15 service connections (as defined in subparagraphs (A) and (B)) or 25 people at any time after the conclusion of the 2-year period, the water supplier shall not be considered a public water system.

(5) The term ''supplier of water'' means any person who owns or operates a public water system.

(6) The term ''contaminant'' means any physical, chemical, biological, or radiological substance or matter in water.

(7) The term ''Administrator'' means the Administrator of the Environmental Protection Agency.

(8) The term ''Agency'' means the Environmental Protection Agency.

(9) The term ''Council'' means the National Drinking Water Advisory Council established under section 300j-5 of this title.

(10) The term ''municipality'' means a city, town, or other public body created by or pursuant to State law, or an Indian Tribe.

(11) The term ''Federal agency'' means any department, agency, or instrumentality of the United States.

(12) The term ''person'' means an individual, corporation, company, association, partnership, State, municipality, or Federal agency (and includes officers, employees, and agents of any corporation, company, association, State, municipality, or Federal agency).

(13)(A) Except as provided in subparagraph (B), the term ''State'' includes, in addition to the several States, only the District of Columbia, Guam, the Commonwealth of Puerto Rico, the Northern Mariana Islands, the Virgin Islands, American Samoa, and the Trust Territory of the Pacific Islands.

(B) For purposes of section 300j-12 of this title, the term ''State'' means each of the 50 States, the District of Columbia, and the Commonwealth of Puerto Rico.

(14) The term ''Indian Tribe'' means any Indian tribe having a Federally recognized governing body carrying out substantial governmental duties and powers over any area. For purposes of section 300j-12 of this title, the term includes any Native village (as defined in section 1602(c) of title 43).

(15) Community water system. - The term ''community water system'' means a public water system that -

(A) serves at least 15 service connections used by year-round residents of the area served by the system; or

(B) regularly serves at least 25 year-round residents.

(16) Noncommunity water system. - The term ''noncommunity water system'' means a public water system that is not a community water system.

The Safe Drinking Water Act Amendments of 1996, referred to in par. (4)(C), is Pub. L. 104-182, Aug. 6, 1996, 110 Stat. 1613. For complete classification of this Act to the Code, see Short Title of 1996 Amendment note set out under section 201 of this title and Tables.



The water in this clarifier appears to be clear or settled. The raw water shown is coming from the bottom of the Glen Canyon dam and is very clean prior to treatment. This makes it difficult to use conventional water treatment methods. It does sound crazy that surface water is free of turbidity, but it happens. This water is also very cold considering that Page, Arizona is probably the hottest city in Arizona.

SDWA Water Quality Information and MCLs

Radionuclides

Alpha Emitters Certain minerals are radioactive and may emit a form of radiation known as alpha radiation. Some people who drink water containing alpha emitters in excess of the EPA standard over many years may have an increased risk of getting cancer.

Beta/photon Emitters Certain minerals are radioactive and may emit forms of radiation known as photons and beta radiation. Some people who drink water containing beta and photon emitters in excess of the EPA standard over many years may have an increased risk of getting cancer.

Combined Radium 226/228 Some people who drink water containing radium 226 or 228 in excess of the EPA standard over many years may have an increased risk of getting cancer.

Radon gas can dissolve and accumulate in underground water sources, such as wells, and in the air in your home. Breathing radon can cause lung cancer. Drinking water containing radon presents a risk of developing cancer. Radon in air is more dangerous than radon in water.

Inorganic Contaminants

Antimony
Asbestos
Barium
Beryllium

Cadmium
Chromium
Copper

Cyanide
Mercury
Nitrate

Nitrite
Selenium
Thallium

Arsenic. Some people who drink water containing arsenic in excess of the EPA standard over many years could experience skin damage or problems with their circulatory system, and may have an increased risk of getting cancer.

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 get 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.

Dental fluorosis, in its moderate or severe forms, may result in a brown staining and/or pitting of the permanent teeth. This problem occurs only in developing teeth, before they erupt from the gums. Children under nine should not drink water that has more than 2 mg/L of fluoride.

Lead typically leaches into water from plumbing in older buildings. Lead pipes and plumbing fittings have been banned since August 1998. Children and pregnant women are most susceptible to lead health risks. For advice on avoiding lead, see the EPA's fact sheet "**Lead in Your Drinking Water**".

Synthetic Organic Contaminants, including Pesticides & Herbicides

2,4-D	Dibromochloropropane	Hexachlorobenzene
2,4,5-TP (Silvex)	Dinoseb	Hexachlorocyclopentadiene
Acrylamide	Dioxin (2,3,7,8-TCDD)	Lindane
Alachlor	Diquat	Methoxychlor
Atrazine	Endothall	Oxamyl [Vydate]
Benzoapyrene	Endrin	PCBs [Polychlorinated biphenyls]
Carbofuran	Epichlorohydrin	Pentachlorophenol
Chlordane	Ethylene dibromide	Picloram
Dalapon	Glyphosate	Simazine
Di 2-ethylhexyl adipate	Heptachlor	Toxaphene
Di 2-ethylhexyl phthalate	Heptachlor epoxide	

Volatile Organic Contaminants

Benzene	trans-1,2-Dichloroethylene	1,2,4-Trichlorobenzene
Carbon Tetrachloride	Dichloromethane	1,1,1,-Trichloroethane
Chlorobenzene	1,2-Dichloroethane	1,1,2-Trichloroethane
o-Dichlorobenzene	1,2-Dichloropropane	Trichloroethylene
p-Dichlorobenzene	Ethylbenzene	Toluene
1,1-Dichloroethylene	Styrene	Vinyl Chloride
cis-1,2-Dichloroethylene	Tetrachloroethylene	Xylenes

New EPA Water Rules

Arsenic

Arsenic is a chemical that occurs naturally in the earth's crust. When rocks, minerals, and soil erode, they release arsenic into water supplies. When people drink this water or eat animals and plants that drink it, they are exposed to arsenic. For most people in the U.S., eating and drinking are the most common ways that people are exposed to arsenic, although it can also come from industrial sources. Studies have linked long-term exposure of arsenic in drinking water to a variety of cancers in humans. To protect human health, an EPA standard limits the amount of arsenic in drinking water. In January 2001, the EPA revised the standard from 50 parts per billion (**ppb**), ordering that it fall to 10 ppb by 2006. After adopting 10ppb as the new standard for arsenic in drinking water, the EPA decided to review the decision to ensure that the final standard was based on sound science and accurate estimates of costs and benefits. Back in October 2001, the EPA decided to move forward with implementing the 10ppb standard for arsenic in drinking water. More information on the rulemaking process and the costs and benefits of setting the arsenic limit in drinking water at 10ppb can be found at: www.epa.gov/safewater/arsenic.html or in the Water Quality Chapter in the Arsenic information section.

ICR Information Collection Rule

The EPA has collected data required by the Information Collection Rule (**ICR**) to support future regulation of microbial contaminants, disinfectants, and disinfection byproducts. The rule is intended to provide the EPA with information on chemical byproducts that form when disinfectants used for microbial control react with chemicals already present in source water (disinfection byproducts (**DBPs**)); disease-causing microorganisms (pathogens), including *Cryptosporidium*; and engineering data to control these contaminants. Drinking water microbial and disinfection byproduct information collected for the ICR is now available in the EPA's Envirofacts Warehouse.

Disinfection Byproduct Regulations

In December 1998, the EPA established the Stage 1 Disinfectants/Disinfection Byproducts Rule that requires public water systems to use treatment measures to reduce the formation of disinfection byproducts and to meet the following specific standards:

Total trihalomethanes (TTHM)	80 parts per billion (ppb)
Haloacetic acids (HAA5)	60 ppb
Bromate	10 ppb
Chlorite	1.0 parts per million (ppm)

Currently trihalomethanes are regulated at a maximum allowable annual average level of 100 parts per billion for water systems serving over 10,000 people under the Total Trihalomethane Rule finalized by EPA in 1979. The Stage 1 Disinfectant/Disinfection Byproduct Rule standards became effective for trihalomethanes and other disinfection byproducts listed above in December 2001 for large surface water public water systems. Those standards became effective in December 2003 for small surface water and all ground water public water systems.

Disinfection byproducts are formed when disinfectants used in water treatment plants react with bromide and/or natural organic matter (i.e., decaying vegetation) present in the source water. Different disinfectants produce different types or amounts of disinfection byproducts. Disinfection byproducts for which regulations have been established have been identified in drinking water, including trihalomethanes, haloacetic acids, bromate, and chlorite.

Trihalomethanes (THM) are a group of four chemicals that are formed along with other disinfection byproducts when chlorine or other disinfectants used to control microbial contaminants in drinking water react with naturally occurring organic and inorganic matter in water. The trihalomethanes are chloroform, bromodichloromethane, dibromochloromethane, and bromoform. The EPA has published the **Stage 1 Disinfectants/Disinfection Byproducts Rule** to regulate total trihalomethanes (**TTHM**) at a maximum allowable annual average level of **80 parts per billion**.

Haloacetic Acids (HAA5) are a group of chemicals that are formed along with other disinfection byproducts when chlorine or other disinfectants used to control microbial contaminants in drinking water react with naturally occurring organic and inorganic matter in water. The regulated haloacetic acids, known as HAA5, are: monochloroacetic acid, dichloroacetic acid, trichloroacetic acid, monobromoacetic acid, and dibromoacetic acid. The EPA has published the **Stage 1 Disinfectants/Disinfection Byproducts Rule** to regulate HAA5 at **60 parts per billion** annual average.

Bromate is a chemical that is formed when ozone used to disinfect drinking water reacts with naturally occurring bromide found in source water. The EPA has established the **Stage 1 Disinfectants/Disinfection Byproducts Rule** to regulate bromate at annual average of **10 parts per billion** in drinking water.

Chlorite is a byproduct formed when chlorine dioxide is used to disinfect water. The EPA has published the **Stage 1 Disinfectants/Disinfection Byproducts Rule** to regulate chlorite at a monthly average level of **1 part per million** in drinking water.

Microbial Regulations

One of the key regulations developed and implemented by the United States Environmental Protection Agency (**USEPA**) to counter pathogens in drinking water is the **Surface Water Treatment Rule**. Among its provisions, the rule requires that a public water system, using surface water (or ground water under the direct influence of surface water) as its source, have sufficient treatment to reduce the source water concentration of ***Giardia*** and viruses by at least 99.9% and 99.99%, respectively.

The Surface Water Treatment Rule specifies treatment criteria to assure that these performance requirements are met; they include turbidity limits, disinfectant residual, and disinfectant contact time conditions.

The **Interim Enhanced Surface Water Treatment Rule** was established in December 1998 to control ***Cryptosporidium*** and to maintain control of pathogens while systems lower disinfection byproduct levels to comply with the **Stage 1 Disinfectants/Disinfection Byproducts Rule**. The EPA established a Maximum Contaminant Level Goal (**MCLG**) of zero for all public water systems and a 99% removal requirement for *Cryptosporidium* in filtered public water systems that serve at least 10,000 people.

The new rule tightened turbidity standards. Turbidity is an indicator of the physical removal of particulates, including pathogens.

The EPA is also planning to develop other rules to further control pathogens. The EPA has promulgated a Long Term 1 Enhanced Surface Water Treatment Rule, for systems serving fewer than 10,000 people, to improve physical removal of *Cryptosporidium*, and to maintain control of pathogens while systems comply with **Stage 1 Disinfectants/Disinfection Byproducts Rule**.

Microbes

Coliform bacteria are common in the environment and are generally not harmful. However, the presence of these bacteria in drinking water is usually a result of a problem with the treatment system or the pipes which distribute water, and indicates that the water may be contaminated with germs that can cause disease.

Fecal Coliform and E. coli are bacteria whose presence indicates that the water may be contaminated with human or animal wastes. Microbes in these wastes can cause short-term effects, such as diarrhea, cramps, nausea, headaches, or other symptoms.

Cryptosporidium is a parasite that enters lakes and rivers through sewage and animal waste. It causes cryptosporidiosis, a mild gastrointestinal disease. However, the disease can be severe or fatal for people with severely weakened immune systems. The EPA and CDC have prepared advice for those with severely compromised immune systems who are concerned about ***Cryptosporidium***.

Giardia lamblia is a parasite that enters lakes and rivers through sewage and animal waste. It causes gastrointestinal illness (e.g. diarrhea, vomiting, and cramps).

National Primary Drinking Water Regulations

Inorganic Chemicals	MCLG ¹ (mg/L) ⁴	MCL ² or TT ³ (mg/L) ⁴	Potential Health Effects from Ingestion of Water	Sources of Contaminant in Drinking Water
Antimony	0.006	0.006	Increase in blood cholesterol; decrease in blood glucose	Discharge from petroleum refineries; fire retardants; ceramics; electronics; solder
Arsenic	none ⁵	0.010	Skin damage; circulatory system problems; increased risk of cancer	Discharge from semiconductor manufacturing; petroleum refining; wood preservatives; animal feed additives; herbicides; erosion of natural deposits
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	Some people who use water containing chromium well in excess of the MCL over many years could experience allergic dermatitis	Discharge from steel and pulp mills; erosion of natural deposits
Copper	1.3	Action Level=1.3 ; TT ⁶	Short term exposure: Gastrointestinal distress. Long term exposure: Liver or kidney damage. Those with Wilson's Disease should consult their personal doctor if their water systems exceed the copper action level.	Corrosion of household plumbing systems; erosion of natural deposits; leaching from wood preservatives
Cyanide (as free cyanide)	0.2	0.2	Nerve damage or thyroid problems	Discharge from 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	Action Level=0.0 15; TT ⁶	Infants and children: Delays in physical or mental development. Adults: Kidney problems; high blood pressure	Corrosion of household plumbing systems; erosion of natural deposits
Inorganic Mercury	0.002	0.002	Kidney damage	Erosion of natural deposits; discharge from refineries and factories; runoff from landfills and cropland

Nitrate (measured as Nitrogen)	10	10	"Blue baby syndrome" in infants under six months - life threatening without immediate medical attention. Symptoms: Infant looks blue and has shortness of breath.	Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits
Nitrite (measured as Nitrogen)	1	1	"Blue baby syndrome" in infants under six months - life threatening without immediate medical attention. Symptoms: Infant looks blue and has shortness of breath.	Runoff from fertilizer use; leaching 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 pharmaceutical companies

Organic Chemicals	MCLG ¹ (mg/L) ⁴	MCL ² or TT ³ (mg/L) ⁴	Potential Health Effects from Ingestion of Water	Sources of Contaminant in Drinking Water
Acrylamide	zero	TT ²	Nervous system or blood problems; increased risk of cancer	Added to water during sewage/wastewater treatment
Alachlor	zero	0.002	Eye, liver, kidney or spleen problems; anemia; increased risk of cancer	Runoff from herbicide used on row crops
Atrazine	0.003	0.003	Cardiovascular system problems; reproductive difficulties	Runoff from herbicide used on row crops
Benzene	zero	0.005	Anemia; decrease in blood platelets; increased risk of cancer	Discharge from factories; leaching from gas storage tanks and landfills
Benzo(a)pyrene	zero	0.0002	Reproductive difficulties; increased risk of cancer	Leaching from linings of water storage tanks and distribution lines
Carbofuran	0.04	0.04	Problems with blood or nervous system; reproductive difficulties.	Leaching of soil fumigant used on rice and alfalfa
Carbon tetrachloride	zero	.005	Liver problems; increased risk of cancer	Discharge from chemical plants and other industrial activities
Chlordane	zero	0.002	Liver or nervous system problems; increased risk of cancer	Residue of banned termiticide
Chlorobenzene	0.1	0.1	Liver or kidney problems	Discharge from chemical and agricultural chemical factories
2,4-D	0.07	0.07	Kidney, liver, or adrenal gland problems	Runoff from herbicide used on row crops
Dalapon	0.2	0.2	Minor kidney changes	Runoff from herbicide used on rights of way
1,2-Dibromo-3-chloropropane (DBCP)	zero	0.0002	Reproductive difficulties; increased risk of cancer	Runoff/leaching from soil fumigant used on soybeans, cotton, pineapples, and orchards
o-Dichlorobenzene	0.6	0.6	Liver, kidney, or circulatory system problems	Discharge from industrial chemical factories
p-Dichlorobenzene	0.075	0.075	Anemia; liver, kidney or spleen damage; changes in blood	Discharge from industrial chemical factories
1,2-Dichloroethane	zero	0.005	Increased risk of cancer	Discharge from industrial chemical factories
1-1-Dichloroethylene	0.007	0.007	Liver problems	Discharge from industrial chemical factories

cis-1, 2-Dichloroethylene	0.07	0.07	Liver problems	Discharge from industrial chemical factories
trans-1,2-Dichloroethylene	0.1	0.1	Liver problems	Discharge from industrial chemical factories
Dichloromethane	zero	0.005	Liver problems; increased risk of cancer	Discharge from pharmaceutical and chemical factories
1-2-Dichloropropane	zero	0.005	Increased risk of cancer	Discharge from industrial chemical factories
Di(2-ethylhexyl)adipate	0.4	0.4	General toxic effects or reproductive difficulties	Leaching from PVC plumbing systems; discharge from chemical factories
Di(2-ethylhexyl)phthalate	zero	0.006	Reproductive difficulties; liver problems; increased risk of cancer	Discharge from rubber and chemical factories
Dinoseb	0.007	0.007	Reproductive difficulties	Runoff from herbicide used on soybeans and vegetables
Dioxin (2,3,7,8-TCDD)	zero	0.00000003	Reproductive difficulties; increased risk of cancer	Emissions from waste incineration and other combustion; discharge from chemical factories
Diquat	0.02	0.02	Cataracts	Runoff from herbicide use
Endothall	0.1	0.1	Stomach and intestinal problems	Runoff from herbicide use
Endrin	0.002	0.002	Nervous system effects	Residue of banned insecticide
Epichlorohydrin	zero	TT ²	Stomach problems; reproductive difficulties; increased risk of cancer	Discharge from industrial chemical factories; added to water during treatment process
Ethylbenzene	0.7	0.7	Liver or kidney problems	Discharge from petroleum refineries
Ethylene dibromide	zero	0.00005	Stomach problems; reproductive difficulties; increased risk of cancer	Discharge from petroleum refineries
Glyphosate	0.7	0.7	Kidney problems; reproductive difficulties	Runoff from herbicide use
Heptachlor	zero	0.0004	Liver damage; increased risk of cancer	Residue of banned termiticide
Heptachlor epoxide	zero	0.0002	Liver damage; increased risk of cancer	Breakdown of heptachlor
Hexachlorobenzene	zero	0.001	Liver or kidney problems; reproductive difficulties; increased risk of cancer	Discharge from metal refineries and agricultural chemical factories
Hexachlorocyclopentadiene	0.05	0.05	Kidney or stomach problems	Discharge from chemical factories
Lindane	0.0002	0.0002	Liver or kidney problems	Runoff/leaching from insecticide used on cattle, lumber, gardens
Methoxychlor	0.04	0.04	Reproductive difficulties	Runoff/leaching from insecticide used on fruits, vegetables, alfalfa, livestock
Oxamyl (Vydate)	0.2	0.2	Slight nervous system effects	Runoff/leaching from insecticide used on apples, potatoes, and tomatoes
Polychlorinated biphenyls (PCBs)	zero	0.0005	Skin changes; thymus gland problems; immune deficiencies; reproductive or nervous system difficulties; increased risk of cancer	Runoff from landfills; discharge of waste chemicals
Pentachlorophenol	zero	0.001	Liver or kidney problems; increased risk of cancer	Discharge from wood preserving factories
Picloram	0.5	0.5	Liver problems	Herbicide runoff
Simazine	0.004	0.004	Problems with blood	Herbicide runoff
Styrene	0.1	0.1	Liver, kidney, and circulatory problems	Discharge from rubber and plastic factories; leaching from landfills
Tetrachloroethylene	zero	0.005	Liver problems; increased risk of cancer	Discharge from factories and dry cleaners

Toluene	1	1	Nervous system, kidney, or liver problems	Discharge from petroleum factories
Total Trihalomethanes (TTHMs)	none ⁵	0.10	Liver, kidney or central nervous system problems; increased risk of cancer	Byproduct of drinking water disinfection
Toxaphene	zero	0.003	Kidney, liver, or thyroid problems; increased risk of cancer	Runoff/leaching from insecticide used on cotton and cattle
2,4,5-TP (Silvex)	0.05	0.05	Liver problems	Residue of banned herbicide
1,2,4-Trichlorobenzene	0.07	0.07	Changes in adrenal glands	Discharge from textile finishing factories
1,1,1-Trichloroethane	0.20	0.2	Liver, nervous system, or circulatory problems	Discharge from metal degreasing sites and other factories
1,1,2-Trichloroethane	0.003	0.005	Liver, kidney, or immune system problems	Discharge from industrial chemical factories
Trichloroethylene	zero	0.005	Liver problems; increased risk of cancer	Discharge from petroleum refineries
Vinyl chloride	zero	0.002	Increased risk of cancer	Leaching from PVC pipes; discharge from plastic factories
Xylenes (total)	10	10	Nervous system damage	Discharge from petroleum factories; discharge from chemical factories

Radionuclides	MCLG ¹ (mg/L) ⁴	MCL ² or TT ³ (mg/L) ⁴	Potential Health Effects from Ingestion of Water	Sources of Contaminant in Drinking Water
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Beta particles and photon emitters	none ⁵	4 millirems per year	Increased risk of cancer	Decay of natural and man-made deposits
Gross alpha particle activity	none ⁵	15 picocuries per Liter (pCi/L)	Increased risk of cancer	Erosion of natural deposits
Radium 226 and Radium 228 (combined)	none ⁵	5 pCi/L	Increased risk of cancer	Erosion of natural deposits

Microorganisms	MCLG ¹ (mg/L) ⁴	MCL ² or TT ³ (mg/L) ⁴	Potential Health Effects from Ingestion of Water	Sources of Contaminant in Drinking Water
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<i>Giardia lamblia</i>	zero	TT ⁸	Giardiasis, a gastroenteric disease	Human and animal fecal waste
Heterotrophic plate count	N/A	TT ⁸	HPC has no health effects, but can indicate how effective treatment is at controlling microorganisms.	n/a
<i>Legionella</i>	zero	TT ⁸	Legionnaire's Disease, commonly known as pneumonia	Found naturally in water; multiplies in heating systems
Total Coliforms (including fecal coliform and <i>E. Coli</i>)	zero	5.0% ⁹	Used as an indicator that other potentially harmful bacteria may be present ¹⁰	Human and animal fecal waste
Turbidity	N/A	TT ⁸	Turbidity has no health effects but can interfere with disinfection and provide a medium for microbial growth. It may indicate the presence of microbes.	Soil runoff
Viruses (enteric)	zero	TT ⁸	Gastroenteric disease	Human and animal fecal waste

National Secondary Drinking Water Regulations

National Secondary Drinking Water Regulations (NSDWRs or 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.

Contaminant	Secondary Standard
Aluminum	0.05 to 0.2 mg/L
Chloride	250 mg/L
Color	15 (color units)
Copper	1.0 mg/L
Corrosivity	noncorrosive
Fluoride	2.0 mg/L
Foaming Agents	0.5 mg/L
Iron	0.3 mg/L
Manganese	0.05 mg/L
Odor	3 threshold odor number
pH	6.5-8.5
Silver	0.10 mg/L
Sulfate	250 mg/L
Total Dissolved Solids	500 mg/L
Zinc	5 mg/L

Notes

¹ Maximum Contaminant Level Goal (**MCLG**) - The maximum level of a contaminant in drinking water at which no known or anticipated adverse effect on the health effect of persons would occur, and which allows for an proper margin of safety. MCLGs are non-enforceable public health goals.

² 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 enforceable standards. The margins of safety in MCLGs ensure that exceeding the MCL slightly does not pose significant risk to public health.

³ Treatment Technique - An enforceable procedure or level of technical performance which public water systems must follow to ensure control of a contaminant.

⁴ Units are in milligrams per Liter (mg/L) unless otherwise noted.

⁵ MCLGs were not established before the 1986 Amendments to the Safe Drinking Water Act. Therefore, there is no MCLG for this contaminant.

⁶ Lead and copper are regulated in a Treatment Technique which requires systems to take tap water samples at sites with lead pipes or copper pipes that have lead solder and/or are served by lead service lines. The action level, which triggers water systems into taking treatment steps if exceeded in more than 10% of tap water samples, for copper is 1.3 mg/L, and for lead is 0.015mg/L.

⁷ Each water system must certify, in writing, to the state (using third-party or manufacturer's certification) that when acrylamide and epichlorohydrin are used in drinking water systems, the combination (or product) of dose and monomer level does not exceed the levels specified, as follows:

- **Acrylamide** = 0.05% dosed at 1 mg/L (or equivalent)
- **Epichlorohydrin** = 0.01% dosed at 20 mg/L (or equivalent)

⁸ The Surface Water Treatment Rule requires systems using surface water or ground water under the direct influence of surface water to (1) disinfect their water, and (2) filter their water or meet criteria for avoiding filtration so that the following contaminants are controlled at the following levels:

- **Giardia lamblia**: 99.9% killed/inactivated
Viruses: 99.99% killed/inactivated
- **Legionella**: No limit, but EPA believes that if **Giardia** and viruses are inactivated, **Legionella** will also be controlled.
- **Turbidity**: At no time can turbidity (**cloudiness of water**) go above 5 nephelometric turbidity units (NTU); systems that filter must ensure that the turbidity go no higher than 1 NTU (0.5 NTU for conventional or direct filtration) in at least 95% of the daily samples in any month.
- **HPC**: NO more than 500 bacterial colonies per milliliter.

⁹ No more than 5.0% samples total coliform-positive in a month. (For water systems that collect fewer than 40 routine samples per month, no more than one sample can be total coliform-positive). Every sample that has total coliforms must be analyzed for fecal coliforms. There cannot be any fecal coliforms.

¹⁰ Fecal coliform and *E. coli* are bacteria whose presence indicates that the water may be contaminated with human animal wastes. Microbes in these wastes can cause diarrhea, cramps, nausea, headaches, or other symptoms.



The above photograph shows a lab technician checking the water for quality changes.



Once chemical feed is determined, changes can be made electronically on the SCADA system.

Understanding the Terms

We are all aware of the potential of Long-term and short-term exposure to Disinfection By-products (DBPs) and how it could cause cancer. There are studies that suggest total trihalomethanes (TTHMs) may be associated with spontaneous abortions in humans. Studies have found THMs negatively affect laboratory animal reproduction and fetal development. The volatile nature of THMs could increase inhalation exposures (An example would be taking a steamy shower), depending on the concentration of the THMs in the receiving water.



The East Verde River, a major source of surface water that supplies the needs of Phoenix and other large cities in Arizona.

The nation's water suppliers, state regulatory agencies, and US Environmental Protection Agency have jointly agreed to implement Stage 1 D/DBP Rule provisions and the most recent Stage 2 D/DBP Rule.

The goal of stage 1 is to optimize treatment at a relatively low cost in order to reduce DBP formation. Stage 2 DBPR bases compliance on calculating a locational running annual average (LRAA) where compliance with the rule requires maintaining the annual average at each compliance sampling location in the distribution system at or below 0.080 mg/L and 0.060 mg/L for TTHM and HAA5, respectively.

The rule requires that certain precursors be monitored and removed. It has been proven that enhanced coagulation in most cases achieves a percent of total organic carbon (TOC). TOC is an indicator of precursors that form THMs and haloacetic acids (HAA).

There are different natural occurring precursors found in rivers, lakes and water sheds. Natural organic matter (NOM) could be measured however the cost is high, so TOC is used as a substitute. TOC is an important indicator because it is considered a precursor to disinfection by-products. Another alternative is specific ultraviolet absorbance (SUVA), how this works UV254 analysis measures the amount of absorption of the cellular structure. Waters with low SUVA values contain primarily non-humic matter and are not amenable to enhanced coagulation. The SUVA would be less than 2.0L/mg-m.



In 2005, Northern Arizona, along with the Four Peaks area, suffered devastating fires. The environmental impact was significant. These photographs show how fires met the shore lines of Lake Roosevelt. Lake Roosevelt serves as a watershed for many municipalities.



Just when you think you got it figured out here comes the Long-Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR). This regulation will apply to all public water systems that use surface water or ground water under the direct influence of surface water (GWUDI). Key provisions in the LT2ESWTR include the following: source water monitoring for Cryptosporidium, with a screening procedure to reduce monitoring costs for small systems; risk-targeted Cryptosporidium treatment by filtered systems with the highest source water Cryptosporidium levels; inactivation of Cryptosporidium by all unfiltered systems; criteria for the use of Cryptosporidium treatment and control processes; and covering or treating uncovered finished water storage facilities.

Filtered systems are not required to conduct source water monitoring if the system will provide a total of at least 5.5-log of treatment for Cryptosporidium. Neither are unfiltered systems that will provide a total of at least 3-log Cryptosporidium inactivation, as this is equivalent to meeting the treatment requirements for unfiltered systems with a mean Cryptosporidium concentration of greater than 0.01 oocysts/L. Otherwise, PWSs using surface water or GWUDI are required to monitor their source water (i.e., the influent water entering the treatment plant) monthly for 24 months to determine an average cryptosporidium level.



Cattle along the Verde River shores.

Large systems must also monitor for E. coli and turbidity in source water. A monitoring schedule is included in the rule language that staggers the required start of monitoring by system size.

The schedule provides for the submission of a sampling plan, conducting sampling, and submission of a report. Systems must adhere to the sampling plan and report results no later than 10 days after the end of the first month following the month when the sample is collected. All systems serving at least 10,000 people must report the results from the initial source water monitoring to the EPA electronically at <https://intranet.epa.gov/lt2/>.

Submission of historical (grandfathered) data is possible when it meets requirements specified in the rule. Systems serving less than 10,000 persons may use E. coli as a surrogate indicator for Cryptosporidium. However, if the E. coli levels are sufficiently high, these systems must undertake Cryptosporidium monitoring.

The rule also includes a second round of Cryptosporidium sampling for all systems. This second round of sampling will take place six years following bin classification, so this deadline will also be staggered by system size.



Community Water System have designated water sampling points as shown above.



This photograph overlooks the flocculation basins at a water treatment plant.

Definition of Enhanced Coagulation

The term "enhanced coagulation" refers to the process of improving the removal of disinfection byproduct (DBP) precursors in a conventional water treatment plant by removal of natural organic matter (NOM) by the addition of coagulant. It has been demonstrated by laboratory research and by pilot-, demonstration-, and full-scale studies. Several researchers have shown that total organic carbon (TOC) in water, used as an indicator of NOM, exhibits a wide range of responses to treatment with aluminum and iron salts (Chowdhury et al., 1997; Edwards et al., 1997; White et al., 1997; Owen et al., 1996; Krasner and Amy, 1995; Owen et al., 1993; James M. Montgomery, 1992; Hubel and Edzwald, 1987; Knocke et al., 1986; Chadik and Amy, 1983; Semmens and Field, 1980; Young and Singer, 1979; Kavanaugh, 1978).

The majority of these studies have been conducted using regular and reagent grade alum ($\text{Al}_2[\text{SO}_4]_3 \cdot 14\text{H}_2\text{O}$ and $\text{Al}_2[\text{SO}_4]_3 \cdot 18\text{H}_2\text{O}$, respectively) as the coagulant, but iron salts also have been shown to be effective for removing TOC from water. Polyaluminum chloride (PACl) and cationic polymers also can be effective for removing TOC. Cationic polymers, (as well as anionic and non-ionic polymers) have proven to be valuable in creating settleable floc when high dosages of aluminum or iron salts are used. Specific organic polymers have been shown to remove color in water treatment applications, but significant TOC removal by organic polymers in conventional facilities has not been demonstrated, and organic polymers may actually increase the TOC level of the water (AWWARF, 1989).

The TOC-based performance standard has been developed for enhanced coagulation and enhanced precipitative softening using a 2-step system. Step 1 requires removal of a specific percentage of influent TOC to demonstrate compliance, based on the TOC and alkalinity of the source water. Step 2 requires enhanced coagulation systems that cannot meet the Step 1 criteria or the alternative compliance criteria to establish an alternative TOC removal percentage for defining compliance.

Applicability of Treatment Technique Requirements

Public water utilities must implement enhanced coagulation or enhanced softening to achieve percent TOC removal levels if:

- ◆ the source water is surface water or ground water under the direct influence of surface water (Subpart H systems); and
- ◆ the utility uses conventional treatment (i.e., flocculation, coagulation or precipitative softening, sedimentation, and filtration).

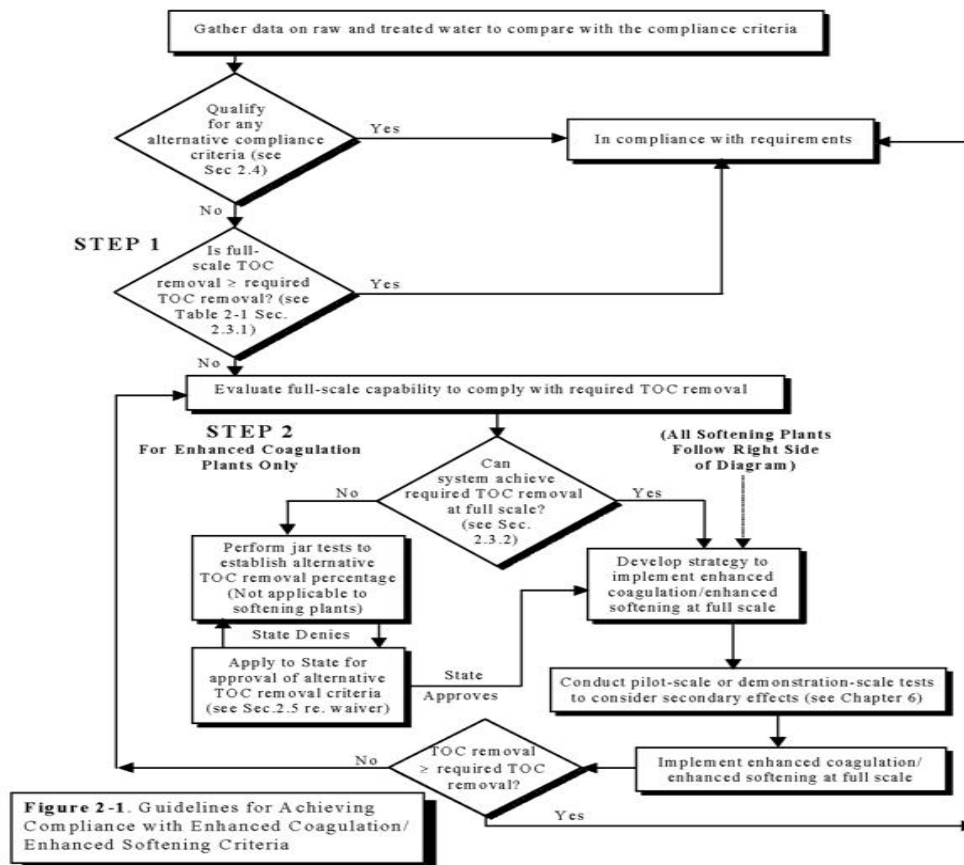
Some types of treatment trains (e.g., direct filtration systems, diatomaceous earth filtration systems, slow sand filtration) and ground water systems are excluded from the enhanced coagulation/enhanced softening requirements because: (1) their source waters are generally expected to be of a higher quality (have lower TOC levels) than waters treated by conventional water treatment plants; and (2) the treatment trains are not typically configured to allow significant TOC removal (i.e., they lack sedimentation basins to settle out TOC).

TOC Removal Performance Requirements

Individual treatment plants are required to achieve a specified percent removal (Step 1) of influent TOC between the raw water sampling point and the treated water TOC monitoring location (no later than the combined filter effluent turbidity monitoring location). Compliance with the TOC removal requirement is based on a running annual average, computed quarterly.

Plants, therefore, will make four compliance determinations each year, one per quarter, based on the most recent four quarters of data. If a plant practicing enhanced coagulation achieves a running annual average removal ratio of less than 1.0 (the ratio of actual percent TOC removal to required percent TOC removal) after the first year of TOC compliance monitoring, and it does not meet any alternative compliance criteria, it is required to perform jar or pilot-scale testing (Step 2 testing) to set an alternative TOC removal requirement, and report the results of testing to the State within three months of failing to achieve a running annual average removal ratio of greater than or equal to 1.0. The alternative removal percentage is subject to State approval. The compliance process is illustrated in Figure 2-1.

Figure 2-1. Guidelines for Achieving Compliance with Enhanced Coagulation/enhanced Softening Criteria



Enhanced softening plants unable to meet the Step 1 TOC removal percentage on a running annual average basis can also establish compliance by achieving either of two softening specific alternative compliance criteria. Enhanced softening plants are not required to perform Step 2 testing to set an alternative TOC removal percentage.

Step One TOC Removal Requirements

Table 2-1 summarizes the percent TOC removal requirements for enhanced coagulation. Enhanced softening plants are required to comply with the TOC removal percentages in the far right column of Table 2-1 (i.e., where alkalinity >120 mg/L as CaCO₃). The percent TOC removals identified in this table are based upon a large database of bench-, pilot-, and full-scale studies at a large number of utilities across the nation (Chowdhury et al., 1997).

The TOC removal criteria presented in Table 2-1 were selected so that a large majority (e.g., 90 percent) of plants required to operate with enhanced coagulation or enhanced softening will be able to meet the TOC removal percentages. Setting the removal criteria this way is expected to result in: (1) smaller transactional costs to the State because fewer evaluations of Step 2 experimental data will be required; and (2) reasonable increases in coagulant doses at affected plants.

TABLE 2-1
Required Removal of TOC by Enhanced Coagulation for Plants Using Conventional Treatment

SOURCE WATER TOC (mg/L)	SOURCE WATER ALKALINITY (mg/L as CaCO ₃)		
	0 to 60	>60 to 120	>120
>2.0-4.0	35.0%	25.0%	15.0%
>4.0-8.0	45.0%	35.0%	25.0%
>8.0	50.0%	40.0%	30.0%

The percent removal requirements specified in Table 2-1 were developed with recognition of the tendency for TOC removal to become more difficult as alkalinity increases and TOC decreases. In higher alkalinity waters, pH depression to a level at which TOC removal is optimal (e.g., pH between 5.5 and 6.5) is more difficult and cannot be achieved easily through the addition of coagulant alone. Compliance with the TOC removal requirements is calculated with a running annual average, computed quarterly.

Month to month changes in source water TOC and/or alkalinity levels will cause some plants to move from one box of Table 2-1 to another. The required TOC removal, therefore, may change month to month based on the TOC and alkalinity level of the monthly source water compliance sample.

Plants not currently in compliance with the values in Table 2-1 may wish to perform jar testing to evaluate modifications to coagulant dose and/or pH conditions to determine whether the required TOC removals can be achieved. If the TOC removal performance criteria identified in Table 2-1 cannot be met, enhanced coagulation systems must implement Step 2.

The Step 2 procedure described here is based on the incremental addition of coagulant to define an alternative TOC removal percentage. Only aluminum or iron-based coagulants may be used for the Step 2 procedure. Addition of acid, polymers, or other treatment chemicals is not permitted. Once the alternative TOC removal percentage is determined via Step 2 testing, a plant may achieve this removal at full-scale using any combination of coagulant, coagulant aid, filter aid, or pH adjustment by acid addition. The goal of the Step 2 procedure is to determine the amount of TOC that can be removed with reasonable amounts of coagulant, and to define an alternative TOC removal percentage. The procedure is not designed nor intended to be used to establish a full-scale coagulant dose requirement.

Monitoring and Reporting

Plants requiring monitoring for TOC removal compliance must develop and implement a monitoring plan. The plant must maintain the plan and make it available for inspection by the State and the general public. Subpart H systems serving more than 3,300 people must submit a copy of the monitoring plan to the State no later than the first time data are submitted to demonstrate compliance with any portion of the DBPR. Following its review, the State may require changes to the monitoring plan. The State also may require monitoring plans to be submitted by other systems. The monitoring plan must include at least the following elements:

- Locations for collecting samples used to demonstrate compliance (frequency and day(s) of sampling also should be included for source and finished water TOC sampling).
- An explanation of the enhanced coagulation/enhanced softening treatment technique to be used, and how the system will calculate compliance with MCLs and MRDLs.

The monitoring plan sampling locations for TTHM and HAA5 must be representative of the entire distribution system if water is provided to consecutive systems, or if the system is approved for monitoring as a consecutive system.

Sampling Location and Monitoring Frequency

TOC

Plants required to implement enhanced coagulation or enhanced softening must monitor for TOC in the source water prior to any treatment, including oxidant addition. Treated water TOC also must be monitored no later than the combined filter effluent turbidity monitoring location. These samples (source water and treated water) are referred to as paired samples. Plants must take a minimum of one paired sample per month per plant at a time representative of normal operating conditions and influent water quality.

Alkalinity

At the time of paired sampling for TOC, the plant also must sample for source water alkalinity at the same location.

Reduced Monitoring for TOC and Alkalinity

Plants may reduce TOC monitoring under the following conditions:

1. Plants with a treated water TOC running annual average of less than 2.0 mg/L for two consecutive years may reduce monitoring for both TOC and alkalinity to one paired sample per plant per quarter, or
2. Plants with a treated water TOC running annual average of less than 1.0 mg/L for one year may reduce monitoring for both TOC and alkalinity to one paired sample per plant per quarter.

Plants under reduced monitoring must revert to routine monitoring in the month following the quarter when the average treated water TOC is greater than or equal to 2.0 mg/L.

Monitoring for Alternative Compliance Criteria

Running annual averages are used to demonstrate compliance with alternative compliance criteria. Four quarters of data are needed to demonstrate that the alternative compliance criteria are being met on a running annual average basis. However, alternative compliance criteria also may be used to demonstrate compliance for a single month.

For example, a plant might not achieve the required Step 1 TOC removal in a given month, but may determine that the finished water SUVA for that monthly sample is less than or equal to 2.0 L/mg-m. The plant is therefore able to assign a value of 1.0 (a value of 1.0 or greater indicates compliance with the TOC removal requirements) for the monthly removal ratio to use in the running annual average compliance calculation.

For months in which alternative compliance criteria are used, a monthly removal ratio of 1.0 must be used for compliance calculations. A plant can demonstrate compliance with enhanced coagulation and enhanced precipitative softening if the criteria listed below are met:

1. Source water TOC < 2.0 mg/L.
2. Treated water TOC < 2.0 mg/L.
3. Source water SUVA $\leq$ 2.0 L/mg-m.
4. Treated water SUVA $\leq$ 2.0 L/mg-m.
5. Source water TOC < 4.0 mg/L, source water alkalinity > 60 mg/L (as CaCO₃), TTHM < 40 ug/L, HAA5 < 30 ug/L.
6. TTHM $\leq$ 40 ug/L and HAA5 $\leq$ 30ug/L with only chlorine for primary disinfection and maintenance of a residual.

Monitoring for TTHM and HAA5

Utilities monitoring to meet alternative compliance requirements must use the TTHM and HAA5 samples used to calculate compliance with the MCLs to determine compliance with alternative compliance criteria 5 and 6. Monitoring locations and sampling frequency for TTHM and HAA5 depend on the source water type and the population served, as shown in Table 4-1.

TABLE 4-1**Monitoring Locations and Sampling Frequency for TTHM and HAA5**

Type of System	Minimum Monitoring Frequency	Sample Location in the Distribution System
Subpart H system serving at least 10,000 persons	Four water samples per quarter per treatment plant	At least 25 percent of all samples collected each quarter at locations representing maximum residence time. Remaining samples taken at locations representative of at least average residence time in the distribution system and representing the entire distribution system, taking into account number of persons served, different sources of water, and different treatment methods. ¹
Subpart H system serving from 500 to 9,999 persons	One sample per quarter per treatment plant ¹	Locations representing maximum residence time. ¹
Subpart H system serving fewer than 500 persons	One sample per year per treatment plant during month of warmest water temperature	Locations representing maximum residence time. ¹ If the sample (or average of annual samples, if more than one sample is taken) exceeds MCL, system must increase monitoring to one sample per treatment plant per quarter, taken at a point reflecting the maximum residence time in the distribution system, until system meets reduced monitoring criteria specified in the regulation.
System using only ground water not under direct influence of surface water, using chemical disinfectant and serving at least 10,000 people	One sample per quarter per treatment plant ²	Locations representing maximum residence time. ¹
System using only ground water not under direct influence of surface water, using chemical disinfectant and serving fewer than 10,000 people	One sample per year per treatment plant ² during month of warmest water temperature	Locations representing maximum residence time. ¹ If the sample (or average of annual samples, if more than one sample is taken) exceeds MCL, system must increase monitoring to one sample per treatment plant per quarter, taken at a point reflecting the maximum residence time in the distribution system, until system meets reduced monitoring criteria specified in the regulation.

¹ If a system elects to sample more frequently than the minimum required, at least 25 percent of all samples collected each quarter (including those taken in excess of the required frequency) must be taken at locations that represent the maximum residence time of the water in the distribution system. The remaining samples must be taken at locations representative of at least average residence time in the distribution system.

² Multiple wells drawing water from a single aquifer may be considered one treatment plant for determining the minimum number of samples required, with State approval in accordance with criteria developed under Part 142.16(h)(5), title 40 Code of Regulations.

Minimum Reporting Levels for DBPs

The rule establishes regulatory minimum reporting limits (MRLs) for compliance reporting of DBPs by public water systems. These regulatory MRLs (figure 11) also define the minimum concentrations that must be reported as part of the Consumer Confidence Reports. Beginning April 1, 2007, report quantitative data for concentrations at least as low as the ones listed in the figure for all DBP samples analyzed for compliance.

Figure 11

Table IV.O-2. Regulatory Minimum Reporting Levels
(Extracted from page 278 of Pre-Publication Stage 2 DBPR [see 71 FR 481])

DBP	Minimum reporting level ¹ (mg/L)	Comments
²		
TTHM		
Chloroform	0.0010	
Bromodichloromethane	0.0010	
Dibromochloromethane	0.0010	
Bromoform	0.0010	
²		
HAA5		
Monochloroacetic Acid	0.0020	
Dichloroacetic Acid	0.0010	
Trichloroacetic Acid	0.0010	
Monobromoacetic Acid	0.0010	
Dibromoacetic Acid	0.0010	
Chlorite	0.020	Applicable to monitoring as prescribed in §141.132(b)(2)(i)(B) and (b)(2)(ii).
Bromate	0.0050 or 0.0010	Laboratories that use EPA Methods 317.0 Revision 2.0, 326.0 or 321.8 must meet a 0.0010 mg/L MRL for bromate.

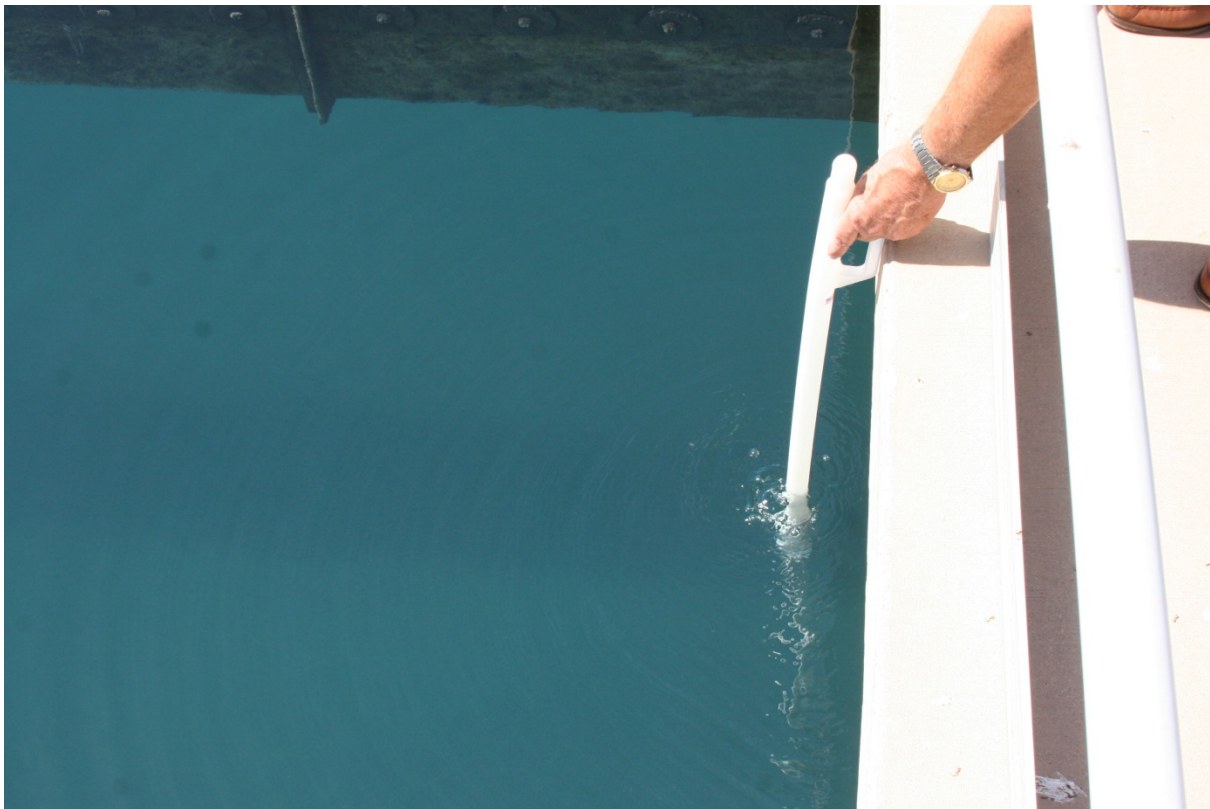
¹ The calibration curve must encompass the regulatory minimum reporting level (MRL) concentration. Data may be reported for concentrations lower than the regulatory MRL as long as the precision and accuracy criteria are met by analyzing an MRL check standard at the lowest reporting limit chosen by the laboratory. The laboratory must verify the accuracy of the calibration curve at the MRL concentration by analyzing an MRL check standard with a concentration less than or equal to 110% of the MRL with each batch of samples. The measured concentration for the MRL check standard must be $\pm 50\%$ of the expected value, if any field sample in the batch has a concentration less than 5 times the regulatory MRL. Method requirements to analyze higher concentration check standards and meet tighter acceptance criteria for them must be met in addition to the MRL check standard requirement.

² When adding the individual trihalomethane or haloacetic acid concentrations to calculate the TTHM or HAA5 concentrations, respectively, a zero is used for any analytical result that is less than the MRL concentration for that DBP, unless otherwise specified by the state.

Maintain TOC < 4 mg/L for Reduced TTHM and HAA5 Monitoring

In order to qualify for reduced routine compliance monitoring for TTHM and HAA5, subpart H systems (i.e., systems that use surface water supplies or ground water under direct influence of surface water) not monitoring to demonstrate compliance with TOC removal requirements of Stage 1 DBPR (i.e., plants that are not conventional filtration designs) must take monthly TOC samples every 30 days at a location prior to any treatment, beginning April 1, 2008 or earlier, if specified by the state. The source water TOC running annual average must be <4.0 mg/L (based on the most recent four quarters of monitoring) on a continuing basis at each treatment plant to reduce or remain on reduced monitoring for TTHM and HAA5. After demonstration of TOC level, the system may reduce monitoring to every 90 days.

Systems on a reduced monitoring schedule may remain on that reduced schedule as long as the average of all samples taken in the year (for systems which must monitor quarterly) or the result of the sample (for systems which must monitor no more frequently than annually) is no more than 0.060 mg/L and 0.045 mg/L for TTHMs and HAA5, respectively.

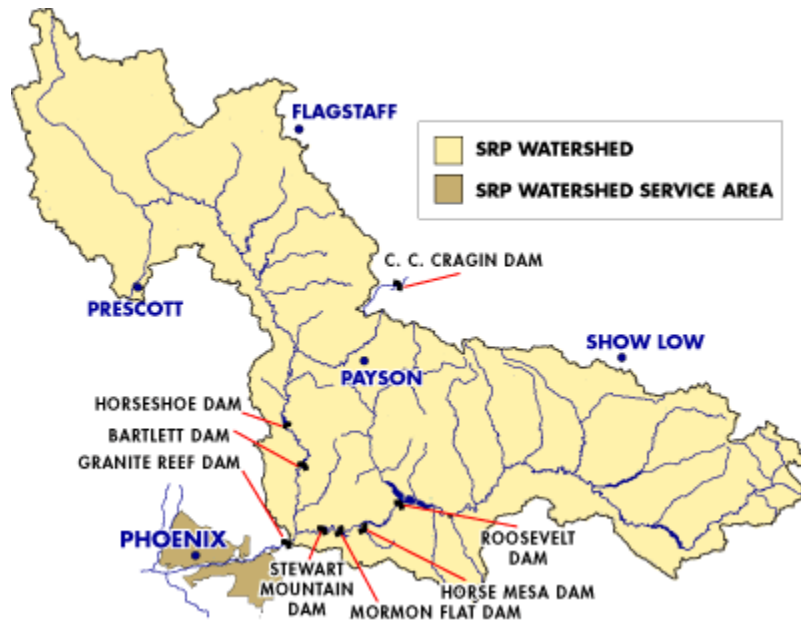


A grab sample being taken from a sedimentation basin to check for TOC removal.

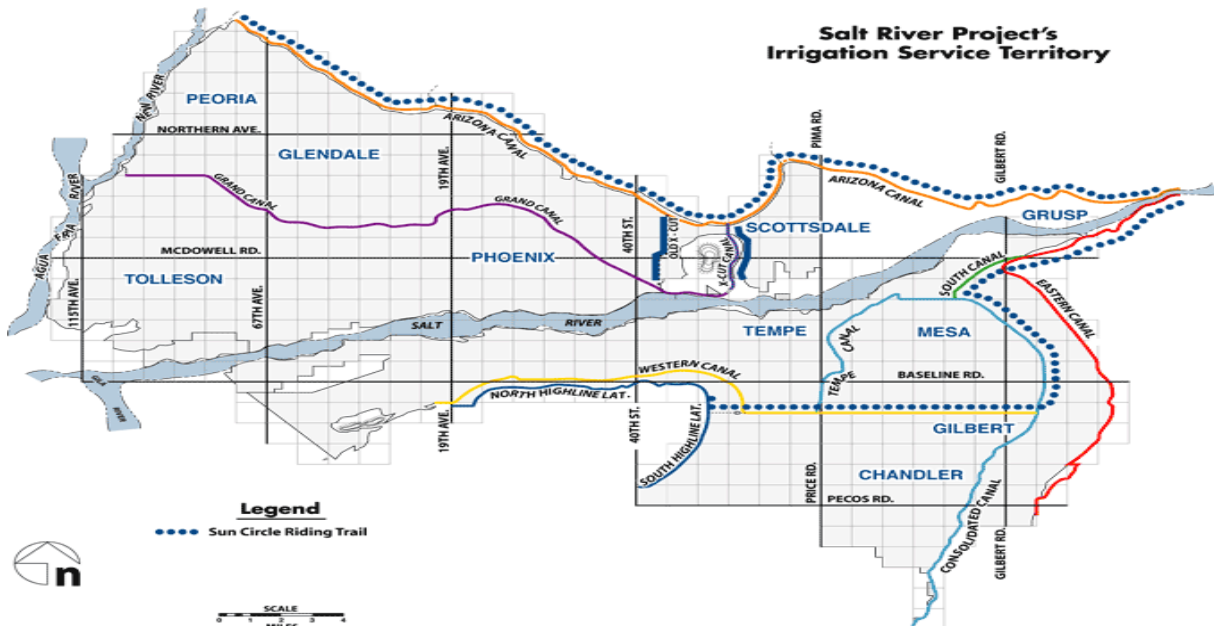
Source of Surface Water

The Valley of the Sun has designated sources of surface water that range from the Central Arizona Project (CAP) aqueduct that stores its water at the Lake Pleasant reservoir and receives water from Salt River Project (SRP) canals. The purpose of the document is to focus on the blending of water and how it affects the quality.

The picture below shows the location of the reservoirs that feed the canal systems.



Depending on the release from the dams, the water then enters the canal systems as shown below.



Depending on the blending of the water from the various water sheds, the quality may have a drastic change. These changes will affect the quality of the water and how the surface water plants treat using enhanced coagulation.

As of June 1st, 2007 the chart below shows the canal source and the amount of flow received.

	Yesterday mean daily	%	Normal	Today
Arizona Canal	712	82	868	747
South Canal	471	60	777	415
Total <i>diversions</i>	1183	72	1645	1162
Pumping	607	121	501	636
Total use	1790	83	2146	1798
Flow over Granite Reef				0

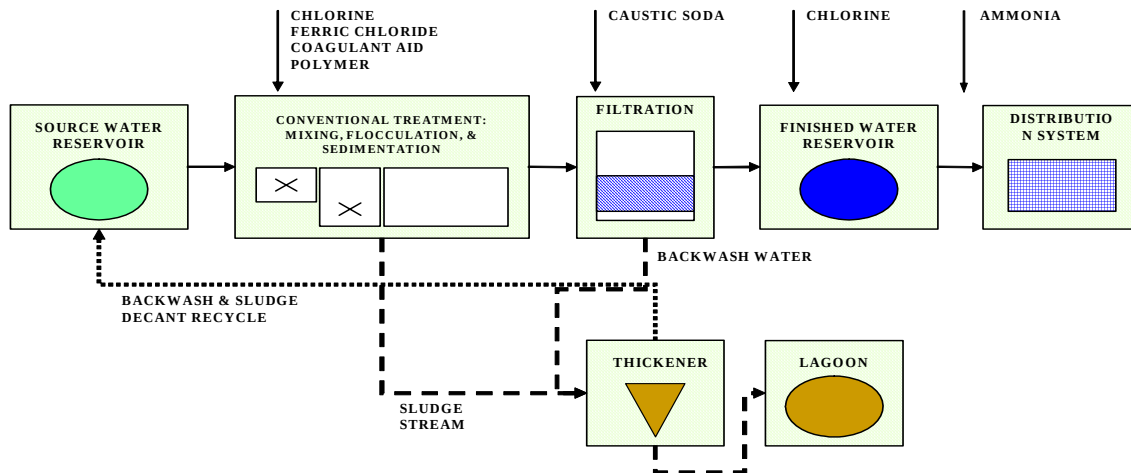
CAP diversions (in cfs) at 0800

Arizona Canal	195
South Canal	49
Riverbed	0
Total	244

Diversions: Canals to which the water is diverted at Granite Reef Diversion Dam once it is released from the reservoirs to satisfy water demand in the Valley.

Overview of Water Treatment

Surface Water Conventional Treatment: 50 MGD



Conventional Plant versus Direct Filtration

The train that is shown above illustrates a typical conventional treatment process. The difference between this plant and a direct filtration plant is that the sedimentation process is not needed in direct filtration. A direct filtration plant receives higher quality water so the concern of TOC is much less. We will focus on the conventional treatment process and how enhanced coagulation reduces TOC.

Pre Sedimentation Plants

Not all Surface Plants have the luxury of post- or pre-treatment. When this process is included heavy inorganics and organic substances may be removed. The types of chemicals used in this process would be Copper sulfate, Powdered activated carbon, Polymer aids and Potassium permanganate just to mention a few. Not only does it benefit in the reduction of NOM it also helps lower TOC.



A large raw water impoundment. You can see the concrete clear well and hard to see but the primary clarifiers are to the right of the photo.

Coagulation

Suspended particles carry an electrical charge which causes them to repel one another. The conventional process uses **alum** (aluminum sulfate) and cationic polymer to neutralize the charge. That allows suspended particles to clump together to form more easily filtered particles.

Alum combines with alkalinity in the raw water to form a white precipitate that neutralizes suspended particles' electrical charge and forms a base for coagulating those particles. Conventional technology uses a 30 to 50 mg/L alum dosage to form a large **floc** that requires extensive retention time to permit settling. Traditional filter systems use graded silica sand filter media. Since the sand grains all have about the same density, larger grains lay toward the bottom of the filter bed and finer grains lay at the top of the filter bed. As a result, filtration occurs only within the first few inches of the finer grains at the top of the bed.

Flocculation

The process of bringing together destabilized or coagulated particles to form larger masses which can be settled and/or filtered out of the water being treated.

In this process, which follows the rapid mixing, the chemically treated water is sent into a basin where the suspended particles can collide, agglomerate (stick together), and form heavier particles called "**floc**". Gentle agitation of the water and appropriate detention times (the length of time water remains in the basin) help facilitate this process.

The water is slowly mixed in contact chambers, allowing the coagulated particles to become larger and stronger and is now called "**floc**." As these floc particles mix in the water, bacteria and other microorganisms are caught in the floc structure.

Sedimentation

The process of suspended solid particles settling out (going to the bottom of the vessel) in water.

Following flocculation, a sedimentation step may be used. During sedimentation, the velocity of the water is decreased so that the suspended material, including flocculated particles, can settle out by gravity. Once settled, the particles combine to form a sludge that is later removed from the bottom of the basin.

Filtration

A water treatment step used to remove turbidity, dissolved organics, odor, taste and color.

The water flows by gravity through large filters of anthracite coal, silica sand, garnet and gravel. The floc particles are removed in these filters. The rate of filtration can be adjusted to meet water consumption needs. Filters for suspended particle removal can also be made of graded sand, granular synthetic material, screens of various materials, and fabrics.

The most widely used are rapid-sand filters in tanks. In these units, gravity holds the material in place and the flow is downwards. The filter is periodically cleaned by a reversal of flow and the discharge of back flushed water into a drain. Cartridge filters made of fabric, paper, or plastic material are also common and are often much smaller and cheaper as well as disposable. Filters are available in several ratings depending on the size of particles to be removed.

Activated carbon filters, described earlier, will also remove turbidity, but would not be recommended for that purpose only. With most of the larger particles settled out, the water now goes to the filtration process. At a rate of between 2 and 10 gpm per square foot, the water is filtered through an approximate 36" depth of graded sand. Anthracite coal or activated carbon may also be included in the sand to improve the filtration process, especially for the removal of organic contaminants and taste and odor problems.

The filtration process removes the following types of particles;

- ❖ Silts and clay
- ❖ Colloids
- ❖ Biological forms
- ❖ Floc

Disinfection

Today, most of our drinking water supplies are free of the micro-organisms — viruses, bacteria and protozoa — that cause serious and life-threatening diseases, such as cholera and typhoid fever. This is largely due to the introduction of water treatment, particularly chlorination, at the turn of the century.

Living cells react with chlorine and reduce its concentration while they die. Their organic matter and other substances that are present convert to chlorinated derivatives, some of which are effective killing agents. Chlorine present as Cl , HOCl , and OCl^- is called **free available chlorine** and that which is bound but still effective is **combined chlorine**. A particularly important group of compounds with combined chlorine is the chloramines formed by reactions with ammonia.

One especially important feature of disinfection using chlorine is the ease of overdosing to create a **"residual"** concentration. There is a constant danger that safe water leaving the treatment plant may become contaminated later. There may be breaks in water mains, loss of pressure that permits an inward leak, or plumbing errors. This residual concentration of chlorine provides some degree of protection right to the water faucet. With free available chlorine, a typical residual is from 0.1 to 0.5 ppm. Because chlorinated organic compounds are less effective, a typical residual is 2 ppm for combined chlorine. There will be no chlorine residual unless there is an excess over the amount that reacts with the organic matter present. However, reaction kinetics complicates interpretation of chlorination data. The correct excess is obtained in a method called **"Break Point Chlorination"**.



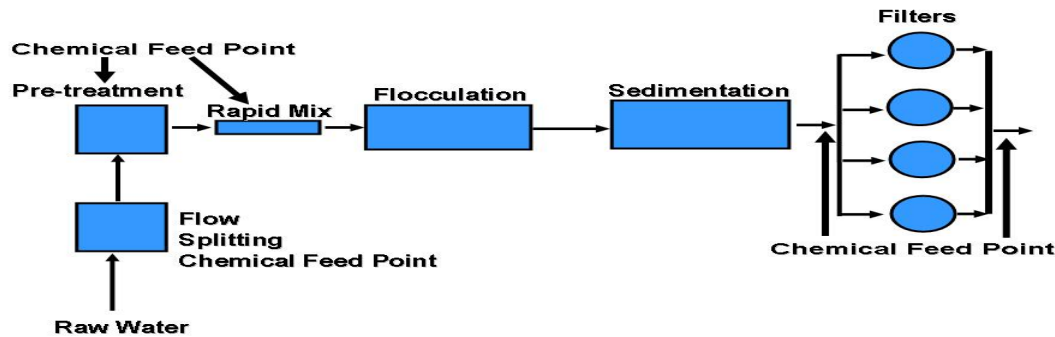
150 pound chlorine gas cylinders on a scale and in service.



This operator is taking a grab sample to measure for turbidity.

The Filtration Process

Removal of suspended solids by filtration plays an important role in the natural treatment of groundwater as it percolates through the soil. It is also a major part of most water treatment. Groundwater that has been softened or treated through iron and manganese removal will require filtration to remove floc created by coagulation or oxidation processes. Since surface water sources are subject to run-off and do not undergo natural filtration, it must be filtered to remove particles and impurities.



The filter used in the filtration process can be compared to a sieve or microstrainer that traps suspended material between the grains of filter media. However, since most suspended particles can easily pass through the spaces between the grains of the filter media, straining is the least important process in filtration.

The photograph on the right illustrates debris removed during the backwash process. The particles are trapped on top of the filter media and trapped within the media.



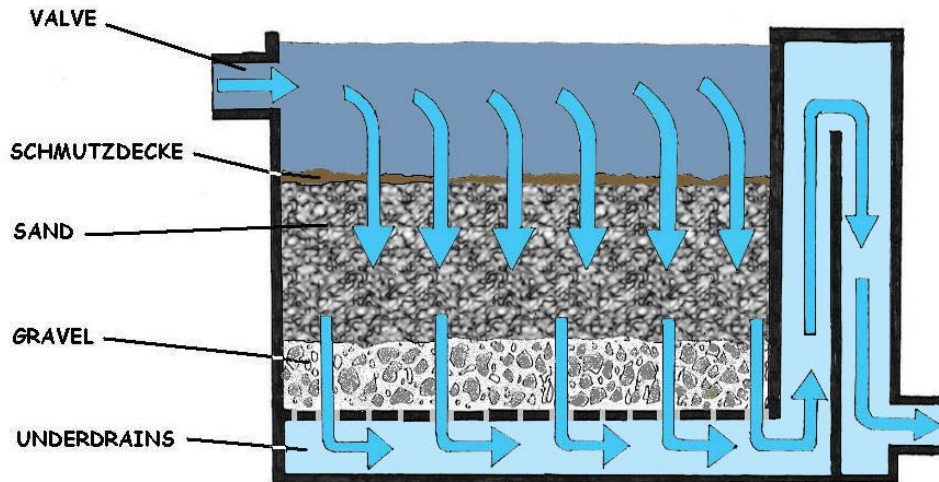
Filtration primarily depends on a combination of complex physical and chemical mechanisms, the most important being adsorption. Adsorption is the process of particles sticking onto the surface of the individual filter grains or onto the previously deposited materials. The forces that attract and hold the particles to the grains are the same as those that work in coagulation and flocculation. In fact, some coagulation and flocculation may occur in the filter bed, especially if coagulation and flocculation of the water before filtration was not properly controlled. Incomplete coagulation can cause serious problems in filter operation.



The bottom photograph shows small glass beads laid on top of a sieve.

Types of Filters

Several types of filters are used for water treatment. The earliest ones developed were the slow sand filters. They typically have filter rates of around 0.05 gpm/ft² of surface area. This type of filter requires large filter areas. The top several inches of the sand has to be removed regularly, usually by hand due to the mass of growing material ("schmutzdecke") that collects in the filter. The sand removed is usually washed and returned to the filter. These filters are still in use in some small plants, especially in the western United States, as well as in many developing countries. They may also be used as a final step in wastewater treatment.



SLOW SAND FILTER

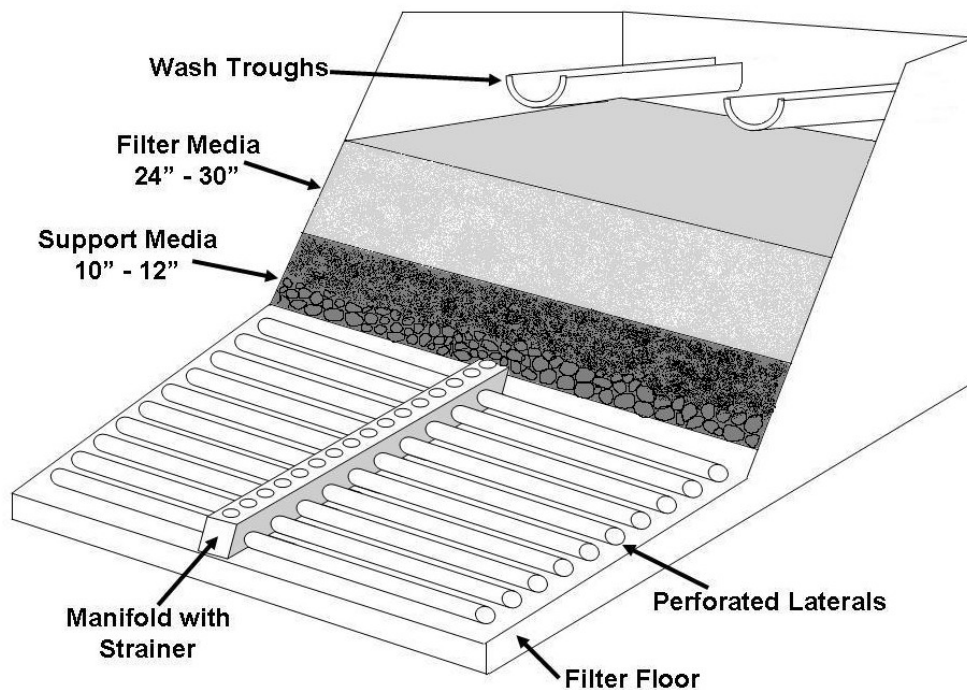
Most filters are classified by filtration rate, type of filter media, or type of operation into:

- A. Gravity Filters
 - 1. Rapid Sand Filters
 - 2. High Rate Filters
 - Dual media
 - Multi-media
- B. Pressure Filters
 - Sand or Multi-media

Rapid Sand Filters

Rapid sand filters can accommodate filter rates 40 times those of slow sand filters. The major parts of a rapid sand filter are:

- ◆ Filter tank or filter box
- ◆ Filter sand or mixed-media
- ◆ Gravel support bed
- ◆ Underdrain system
- ◆ Wash water troughs
- ◆ Filter bed agitators



The filter tank is generally constructed of concrete and is most often rectangular. Filters in large plants are usually constructed next to each other in a row, allowing the piping from the sedimentation basins to feed the filters from a central pipe gallery. Some smaller plants are designed with the filters forming a square of four filters with a central pipe gallery feeding the filters from a center well.

Filter Sand

The filter sand used in rapid sand filters is manufactured specifically for the purpose of water filtration. Most rapid sand filters contain 24-30 inches of sand, but some newer filters are deeper. The sand used is generally 0.4 to 0.6 mm in diameter. This is larger than the sand used in slow rate filtration. The coarser sand in the rapid filters has larger voids that do not fill as easily.

The gravel installed under the sand layer(s) in the filter prevents the filter sand from being lost during the operation. The under-gravel also distributes the backwash water evenly across the total filter. This under-gravel supports the filter sand and is usually graded in three to five layers, each generally 6-18 inches in thickness, depending on the type of underdrain used.

Underdrain

The filter underdrain can be one of many types, such as:

- ◆ Pipe laterals
- ◆ False floor
- ◆ Leopold system
- ◆ Porous plates or strainer nozzles
- ◆ Pipe laterals

A pipe lateral system uses a control manifold with several perforated laterals on each side. Piping materials include cast iron, asbestos cement, and PVC. The perforations are usually placed on the underside of the laterals to prevent them from plugging with sand. This also allows the backwash to be directed against the floor, which helps keep the gravel and sand beds from being directly disturbed by the high velocity water jets.

False floor

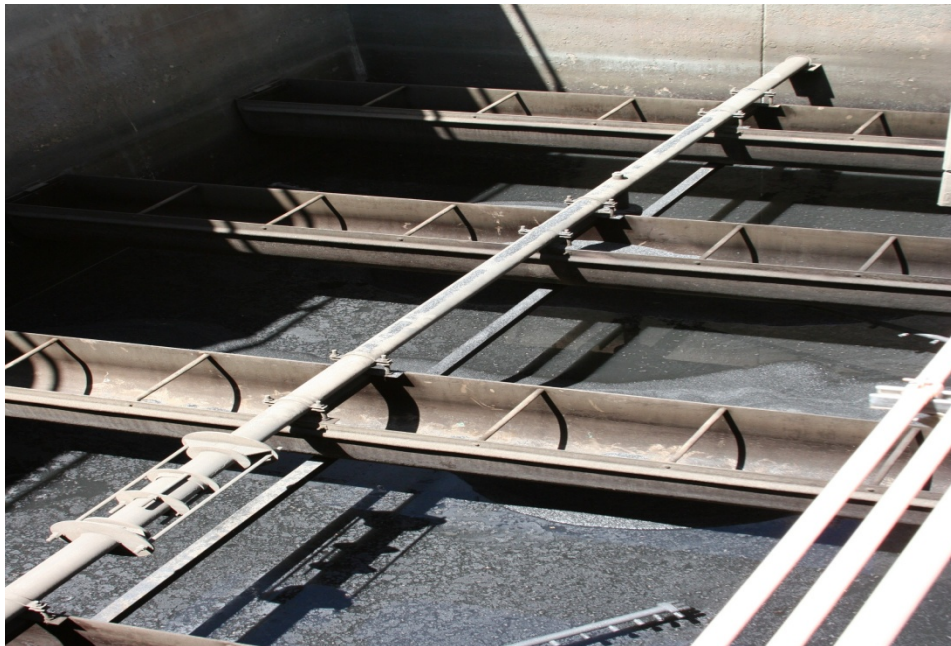
The false floor design of a filter underdrain is used together with a porous plate design or with screens that retain the sand when there is no undergravel layer. This type of underdrain allows the plenum or open space under the floor to act as the collection area for the filtered water and for the distribution of the filter backwash water.

Leopold system

The Leopold system consists of a series of clay or plastic blocks that form the channels to remove the filtered water from the filter and distribute the backwash water. This type of underdrain is generally used with an undergravel layer, although some new designs allow for sand retention without gravel.

Washwater Troughs

Washwater troughs placed above the filter media collect the backwash water and carry it to the drain system. Proper placement of these troughs is very important to ensure that the filter media is not carried into the troughs during the backwash and removed from the filter. The wash troughs must be installed at the same elevation so that they remove the backwash evenly from the filter and so that an even head is maintained across the entire filter. These backwash troughs are constructed from concrete, plastic, fiberglass, or other corrosion-resistant materials.



The photograph above shows exposed filter troughs.

Surface Wash



The photograph above shows a drained filter with the agitator and nozzles exposed. During operation these will spin spraying water during the water backwash.

During the operation of a filter, the upper six-to-ten inches of the filter media remove most of the suspended material from the water. It is important that this layer be thoroughly cleaned during the backwash cycle. Normal backwashing does not, in most cases, clean this layer completely; therefore, some method of agitation is needed to break up the top layers of the filter and to help the backwash water remove any material caught there.



The surface wash system consists of a series of pipes installed in the filter that introduce high velocity water or air jet action into the upper layer of the filter. This jet action will generally be supplied by rotating arms that are activated during the backwashing of the filter. A newer design of surface wash uses compressed air to mix the upper layer and loosen the particles from the sand so that the backwash water can remove the particles more easily. This air wash generally is turned on before the backwash cycle.

If both are used at the same time, some sand may be washed away. The compressed air rate can be two-to-five cubic feet per minute per square foot (cfm/ft²) of filter surface, depending on the design of the filter.

High Rate Filters

High rate filters, which operate at a rate three-to-four times that of rapid sand filters, use a combination of different filter media, not just sand. The combinations vary with the application, but generally they are sand and anthracite coal. Multi-media or mixed-media filters use three or four different materials, generally sand, anthracite coal, and garnet.



In this photograph you can see the water lines on the wall of the filter. The deeper the water the more head pressure exerted on the filter media.

In rapid sand filters, finer sand grains are at the top of the sand layer with larger grains farther down into the filter. As a result, the filter removes more suspended material in the first few inches of the filter. In the high rate filter, the media size decreases. The top layers consist of a coarse material with the finer material farther down, allowing the suspended material to penetrate deeper into the filter.

The material in a filter bed forms layers in the filter, depending on their weight and specific gravities. In the coarse layer at the top, the larger suspended particles are removed first, followed by the finer materials. This allows for longer filter runs at higher rates than is possible with rapid sand filters. The type of filter media used in a high rate filter depends on many factors, including the raw-water quality, raw-water variations, and the chemical treatment used. Pilot studies help the operator evaluate which material, or combination of materials, will give the best result.



Pressure Filters

Pressure filters fall into two categories: pressure sand and diatomite filters.

Pressure Sand Filters

This type of filter is used extensively in iron and manganese removal plants.

A pressure sand filter is contained under pressure in a steel tank, which may be vertical or horizontal, depending on the space available. As with gravity filters, the media is usually sand or a combination of media. Filtration rates are similar to gravity filters.

These filters are commonly used for iron and manganese removal from groundwater, which is first aerated to oxidize the iron or manganese present, then pumped through the filter to remove the suspended material.



Filter Media

Because the water is under pressure, air binding will not occur in the filter. However, pressure filters have a major disadvantage in that the backwash cannot be observed; in addition, cracking of the filter bed can occur quite easily, allowing the iron and manganese particles to go straight through the filter. When using pressure filters for iron and manganese removal, the operator must regularly measure the iron and manganese concentration of the filter effluent and backwash the filter before breakthrough occurs. Because of these limitations, pressure filters must not be used to treat surface water.

Diatomaceous Earth Filter

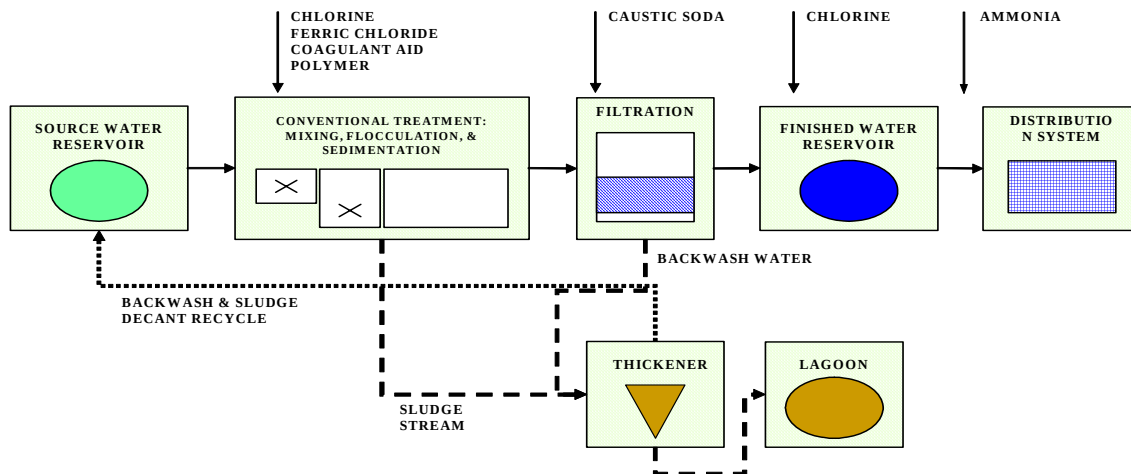
This type of filter is commonly used for the treatment of swimming pools. The process was developed by the military during World War II to remove microorganisms that cause amoebic dysentery from water used in the field.



Filtration Processes

Two basic types of filtration processes are currently used in the United States. Conventional filtration, the traditional design for many years, provides effective treatment for just about any range of raw-water turbidity. Its success is due partially to the sedimentation that precedes filtration and follows the coagulation and flocculation steps. Sedimentation, if operated properly, should remove most of the suspended material.

Surface Water Conventional Treatment: 50 MGD



After sedimentation, the water passing through to the filters should not have turbidity higher than 10-to-15 NTU. Rapid sand filters were once used in the conventional process, but many have been converted to multi-media filters in an attempt to increase plant capacity.

In the other type of filtration process--direct filtration--no sedimentation follows the coagulation phase. Direct filtration is designed to filter water with an average turbidity of less than 25 NTU. Dual and multi-media filters are used with direct filtration. They are able to remove more suspended material per cubic foot of filter media than sand filters. Direct filtration plants have a lower capital cost.

However, the process cannot handle large variations in raw water turbidity.



Filtration Operation

Filtration operation is divided into three steps: filtering, backwashing, and filtering to waste.

Filter Control of the filter operation requires the following equipment:

- ◆ Rate of flow controller
- ◆ Loss of head indicator
- ◆ On-line turbidimeter

Rate of Flow Controllers

Flow rates through filters are controlled by one of two different methods:

Declining rate

This method of control is used where the head loss through the plant is quite large. It allows the filter head to increase until the filter becomes plugged with particles and the head loss is too great to continue operation of the filter. The rate through the filter is much greater in the beginning of a filter run than at the end when the filter is dirty. This method tends to be the most commonly installed in new filter plants.

The photograph above shows operators walking through the filter gallery of a plant that uses declining rate filters. This is also showing pipelines to and from the filter boxes.



Constant rate

This type of control monitors the level of water on the top of the filter and attempts to control this level from the start of the operation to the end. This is accomplished by the controller operating a valve on the effluent of the filter. The valve will be nearly closed at the start of the filter run and fully open at the end. This design is used when the head or pressure on the filter is limited.

The photograph below shows the overflow in case the filter level gets too high.



Both controllers consist of a venturi tube or some other type of metering device, as well as a valve to control the flow from the filter. In most cases, the valve is controlled by an automatic control device, often an air-actuated type valve that is controlled by the flow tube controller.

Loss of head indicator

As filtration proceeds, an increasing amount of pressure, called head loss across the filter, is required to force the water through the filter. The head loss should be continuously measured to help determine when the filter should be backwashed.

Usually the difference in the head is measured by a piezometer connected to the filter above the media and the effluent line.

In-line turbidimeter

Turbidity in water is caused by small suspended particles that scatter or reflect light so that the water appears to be cloudy. Turbidity of the filtered water may shelter bacteria, preventing chlorine from reaching it during the final disinfection process.

The turbidity of the filtered water is one of the factors that determine the length of a filter run. At some point, the suspended material will start to break through the filter media and increase the turbidity of the filter effluent.

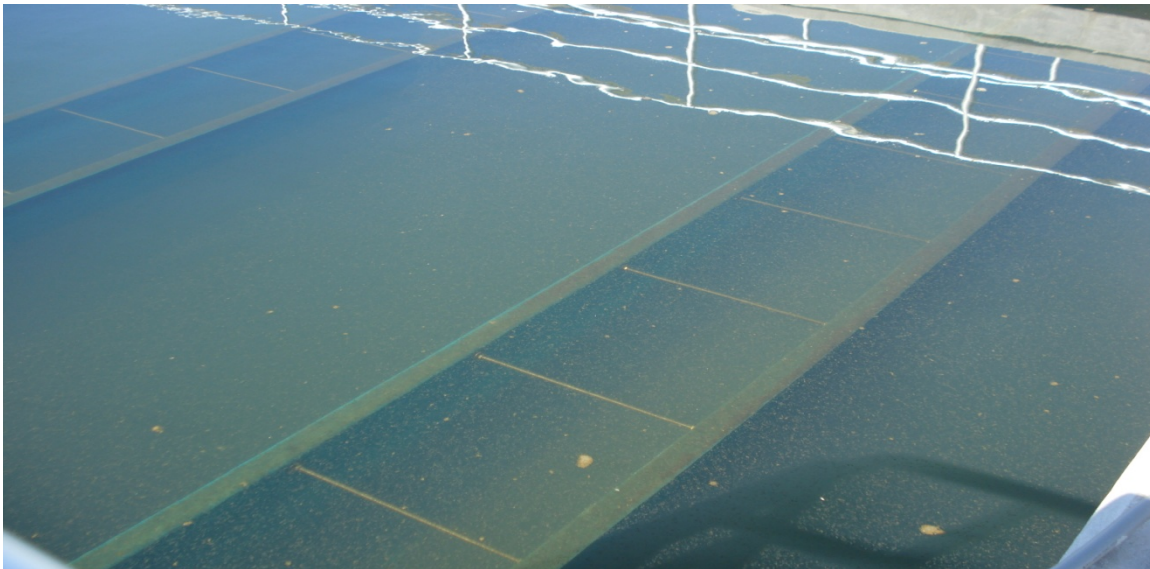
At this time, the filter should be backwashed. Continuous turbidity monitors provide information about when the filter is approaching this point so that the operators can start the backwash before the turbidity is too great. Turbidity measurements will also indicate whether the coagulation and other treatment processes are operating properly.



Filtration Process

Water from the source or, more commonly, from pre-treatment processes, is applied to the top of the filter; it then flows downward. The water level above the filter bed is usually kept at two-to-six feet. When the filtration is started after being backwashed, there will be little head loss. In filters with a control valve installed on the filter effluent pipe, the filter flow is restricted during this time. The control valve also has the important function of preventing filter surges, which could disturb the media and force floc through the filter.

The rate of flow on a filter depends on the type of filter. A rapid sand filter will have a flow of two-to-three gpm/square foot of filter area. The high rate filter may have four-to-six gpm/square foot applied to the surface. A constant rate flow valve is almost fully closed when a filter is clean so that the desired water level on top of the filter is maintained. As the filter becomes dirty with suspended material, the valve opens gradually until the increase in the water level above the filter indicates that the filter needs backwashing.



The above photograph is a filter from a direct filtration plant; notice the size of the floc?

In filters with variable declining rate flow control, the filters are allowed to take on as much water as they can handle. As the filters become dirty, both the headloss and the depth of the water on the surface increase until the filters need backwashing. This method is generally preferred because it requires less operator attention. With this method, a filter accepts as much flow as it can handle. As the filter becomes dirty, the flow through the filter becomes less and, if the plant has more than one filter, additional flow redistributes across the other filters. A flow restrictor is placed in the filter effluent pipe to prevent a filter inflow that is too great for the filter.

Regardless of the method of control, the filter eventually fills with suspended material. At some time, usually after 15 to 30 hours, it will need to be backwashed to clean the media.

Back Washing

Proper backwashing is a very important step in the operation of a filter. If the filter is not backwashed completely, it will eventually develop additional operational problems. If a filter is to operate efficiently, it must be cleaned before the next filter run. Treated water from storage is used for the backwash cycle. This treated water is generally taken from elevated storage tanks or pumped in from the clear well.

During filtration, the filter media becomes coated with the floc, which plugs the voids between the filter grains, making the filter difficult to clean. The media must be expanded to clean the filter during the backwash. This expansion causes the filter grains to violently rub against each other, dislodging the floc from the media.

The filter backwash rate has to be great enough to expand and agitate the filter media and suspend the flocs in the water for removal. However, if the filter backwash rate is too high, media will be washed from the filter into the troughs and out of the filter. A normal backwash rate is between 12 to 15 gpm per square foot of filter surface area.

In most cases the filter backwash rate will not break up the mass on the top of the filter. The design engineer will recommend the installation of a surface wash of some type, the most common being a set of rotary arms that are suspended above the media during filtration. During filter backwash, the media expands upwards and around the washing arms. A newer method of surface wash involves using air scour before the water wash. This is a very efficient method, but requires the installation of a large air blower to produce the air. The normal design for the air wash will be two-to-five cubic feet of air per square foot of filter area.

The photograph above and below both are part of the backwash equipment for the water plant.



The filter should be backwashed when the following conditions have been met:

- ◆ The head loss is so high that the filter no longer produces water at the desired rate; and/or
- ◆ Floc starts to break through the filter and the turbidity in the filter effluent increases; and/or
- ◆ A filter run reaches a given hour of operation.
- ◆ If a filter is taken out of service for some reason, it must always be backwashed prior to be putting on line.

The decision to backwash the filter should not be based on only one of the above conditions. If a filter is not backwashed until the headloss exceeds a certain number of feet, the turbidity may break through and cause the filter to exceed the standard of 0.5 NTU of turbidity.

Similarly, depending on filter effluent- turbidity alone can cause high head loss and decreased filter flow rate, which can cause the pressure in the filter to drop below atmospheric pressure and cause the filter to air bind and stop filtering.

If the water applied to a filter is very good quality, the filter runs can be very long. Some filters can operate longer than one week before needing to be backwashed. However, this is not recommended as long filter runs can cause the filter media to pack down so that it is difficult to expand the bed during the backwash.

Backwashing Process

The normal method for backwashing a filter involves draining the water level above the filter to a point six inches above the filter media. The surface wash is then turned on and allowed to operate for several minutes to break up the crust on the filter. After that, the backwash valve is opened, allowing backwash water to start flowing into the filter and start carrying suspended material away from the filter. For a filter with an air wash instead of a water-surface wash, the filter backwash water and the air wash should not be used together. This would be possible only if some means of controlling the media carryover is installed.





This is a water treatment filter control panel.

The time elapsed from when the filter wash is started until full flow is applied to the filter should be greater than one minute. After a few minutes, the filter backwash valve should be fully opened to allow full expansion of the filter media. Generally, this expansion will be from 20 to 40 percent over the normal filter bed volume. The expansion needed will depend on how much agitation is needed to suspend the filter media to remove suspended material trapped in the filter. With a multi-media filter, the rate must be high enough to scrub the interface between the coal and the sand, where the highest amount of suspended solids will be removed from the media. The filter will be washed for 10 to 15 minutes, depending on the amount of solids that must be removed. The best way to determine how long the filter should be washed is to measure the turbidity of the backwash water leaving the filter. In most cases, a filter is washed too long. This could be costly. Too much backwash water is used, and it must be treated after use. Backwash valves must be opened slowly. Opening the valves too rapidly can cause serious damage to the filter underdrain, filter gravel, and filter media.

Disposal of Filter Backwash Water

Water from the filter backwash cannot be returned directly to the environment. Normally the water is discharged into a backwash tank and allowed to settle. The supernatant, or cleared liquid, is then pumped back to the head of the treatment plant at a rate not exceeding ten percent of the raw water flow entering the plant. The settled material is pumped to a sewer or is treated in the solids-handling process of the plant. This conserves most of the backwash water and eliminates the need to obtain a pollution discharge permit for the disposal of the filter backwash water.



Since backwash is a very high flow operation, the surges that are created from the backwash coming from the filter must not be allowed to enter the head of the plant. Therefore, the spent backwash water must be stored in storage tanks and returned slowly to the treatment process.

Filter to Waste

When filtration is started after backwash, filtered water should be wasted until the turbidity in the effluent meets standards. Depending on the type of filter, this may last from two to 20 minutes. This wasting is needed as some suspended material remains in the filter media following the backwash. The media needs to become somewhat sticky again to start to capture the suspended material.

Also, the filtration rate is higher in a clean filter, causing more material to be swept from the filter during the start-up. Filtration should always be started slowly after a backwash to prevent breakthrough of suspended material.



Filter Aids

Sometimes, when water passes through a filter, the floc is torn apart into smaller particles that will penetrate deeply into the filter media, causing premature turbidity breakthrough. This will require more frequent filter backwashing of the filter and use of large volumes of backwash water to be able to remove the floc that has penetrated deeply into the filter bed.

A filter aid is a material that adds strength to the floc and prevents its breakup. Generally, a polymer is used as a filter aid because it creates strong bonds with the floc. Polymers are water-soluble, organic compounds that can be purchased in either wet or dry form.





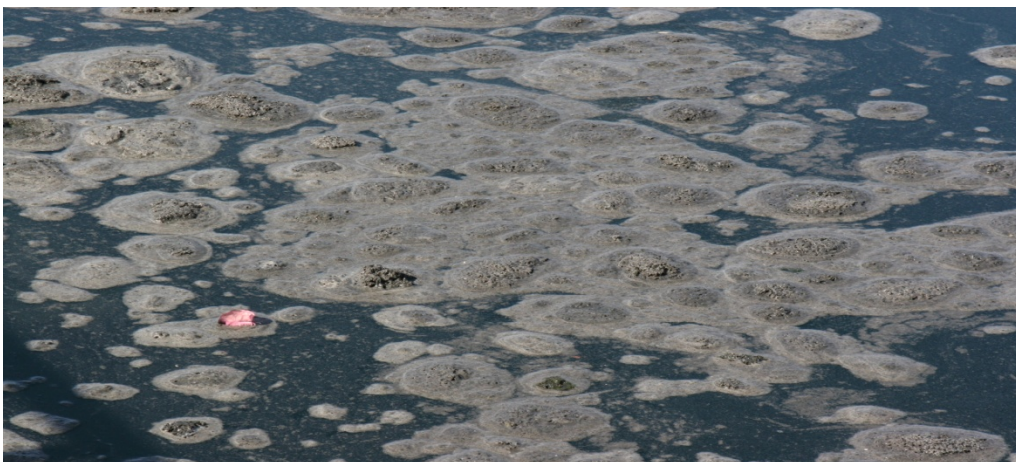
The photograph on the right is dry Polymer and on the left is liquid.

Polymers have very high molecular weight and cause the floc to coagulate and flocculate quickly. Polymers can have positive or negative charges, depending on the type needed to cause attraction to the specific floc filtered.

When used as a filter aid, the polymer strengthens the bonds and prevents the shearing forces in the filter from breaking the floc apart. For best results, the polymer should be added just ahead of the filter. A normal dose of polymer for filter aiding will be less than 0.1 ppm, but the exact dose will be decided by the result of a jar test and by experimentation in the treatment plant. Too much polymer will cause the bonds to become too strong, which may then cause the filter to plug, especially the top few inches of the filter media.

Filter Operating Problems

There are three major types of filter problems. They can be caused by chemical treatment before the filter, control of filter flow rate, and backwashing of filters.



The above photograph shows clumps formed by Powder Activated Carbon.

Chemical Treatment before the Filter

The coagulation and flocculation stages of the water treatment must be monitored continuously. Adjustments in the amount of coagulant added must be made frequently to prevent the filter from becoming overloaded with suspended material. This overload may cause the filter to prematurely reach its maximum headloss.

If there is early turbidity breakthrough in the filter effluent, more coagulant may have to be added to the coagulation process. There may be a need for better mixing during the coagulation or the addition of more filter aid.

Filter aid being fed at the weirs of sedimentation.



If there is a rapid increase in filter head loss, too much coagulant may be clogging the filter. Less coagulant or less filter aid should be used. The operator needs to learn to recognize these problems and choose the proper corrections.



In the photograph above, overfeeding flocculants to meet federal regulations caused Iron to precipitates on the filter walls.

Control of Filter Flow Rate

When a filter is subjected to rapid changes in flow rate, the turbidity of the effluent may be affected; the dirtier the filter media, the greater the effect.

When a plant flow changes, the filter flow also has to change to produce the water needed. If an increase is necessary, the flow should, if possible, be increased gradually over a ten-minute period to reduce the impact on the filter. Addition of filter aids may also reduce the impact on the filter effluent.

When backwashing a filter and therefore temporarily taking it out of service, the remaining filter(s) must pick up the additional flow. This can cause an abrupt change in flow that will cause turbidity breakthrough. This problem can be avoided by keeping one filter in reserve to accept this additional flow. If the plant has a backwash storage basin, this will also prevent surges to the filters.

Filter	Filter	Filter	Filter	Filter	Filter	Filter	Filter	Filter	Filter	Filter	Filter	Filter		
Available	1	1												
Available	2	2												
Available	3	3												
Available	4	4												
Available	5	5												
Available	6	6												
Available	7	7												
Available	8	8												
Available	9	9	Filter No.9	DCS	Add									
Available	10	10	Filter No.10	DCS	Add									
Available	11	11	Filter No.11	DCS	Add									
Available	12	12	Filter No.12	DCS	Add	Enabled	0.08	0.25	29.5	60.0	5.27	1.00	3.07	6.00
Available	13	13	Filter No.13	DCS	Add									
Available	14	14	Filter No.14	DCS	Add	Enabled	0.09	0.30	9.6	72.0	7.36	1.00	3.98	6.00
Available	15	15	Filter No.15	DCS	Add									
Available	16	16	Filter No.16	DCS	Add	Enabled	0.08	0.25	47.7	60.0	7.30	1.00	6.57	7.00
			Filter No.17	DCS	Add	Enabled	0.08	0.25	39.5	60.0	7.18	1.00	6.78	6.00
			Filter No.18	DCS	Add	Enabled	0.08	0.25	14.2	60.0	8.60	1.00	5.83	6.00
			Filter No.19	DCS	Add									
			Filter No.20	DCS	Add									
			Filter No.21	DCS	Add	Enabled	0.07	0.25	50.2	60.0	7.64	1.00	5.38	6.00
			Filter No.22	DCS	Add	Enabled	0.10	0.30	5.2	60.0	7.42	1.00	3.90	6.00
			Filter No.23	DCS	Add									
			Filter No.24	DCS	Add	Enabled	0.08	0.25	15.1	60.0	8.31	1.00	4.87	6.00

PLANT 2

EXIT

Many plants are not operated continuously, and the start-up at the beginning of the day will cause a surge to the filter(s). The filters should be backwashed before putting them back into operation or operated to waste until the effluent meets the standards.

Backwashing of Filters

Backwashing of the filters is the single most important operation in the maintenance of the filters. If the filter is not backwashed effectively, problems may occur that may be impossible to correct without totally replacing the filter media. These problems could be caused by improper backwashing procedures:

- Mud balls are formed by the filter media cementing together with the floc that the filter is supposed to remove. If the filter is backwashed effectively, the mud balls are broken apart and removed. As the balls gain weight, they will settle to the bottom of the filter and occupy valuable filter volume. This will cause the flow to increase in the areas of the filter that have not been plugged. Additional problems, such as filter cracking and separation of the media from the filter walls may also be the result of mud-ball formation.

- ◆ Filter bed shrinkage or compaction can result from ineffective backwashing. Media grains in a clean filter rest directly against each other with very little compaction. Filter media in a dirty filter are surrounded by a soft layer which causes it to compact. This causes filter bed cracking and separation of the filter media from the walls of the filter. When the filter is cracked, it is obvious that the filter will short circuit. The flow will seek the crack and go straight through, resulting in excessive turbidity in the effluent.



A photograph of a backwash basin that has media caked on the bottom.

- ◆ Separation of the gravel is caused by the backwash valve opening too quickly; as a result, the supporting gravel is forced to the top of the filter. This could also be caused by the filter underdrain being plugged, causing uneven distribution of the backwash water. When this happens, a boil occurs from the increased velocity in the filter. The filter media will start washing into the filter underdrain system and be removed from the filter. If displacement has occurred, the filter media must be removed from the filter and the filter rebuilt by the placement of each grade of media in its proper place.
- ◆ Air binding of the filter is not common as long as the filter is washed regularly. Air binding is the result of pressure in the filter becoming negative during operation. This causes the air dissolved in the water to come out of the solution and become trapped in the filter, resulting in resistance and short filter runs. This negative head generally occurs in a filter that has less than five feet of head above the unexpanded filter bed. If a filter head of five feet is not possible, filter backwash should be started at a lower head loss than normal.



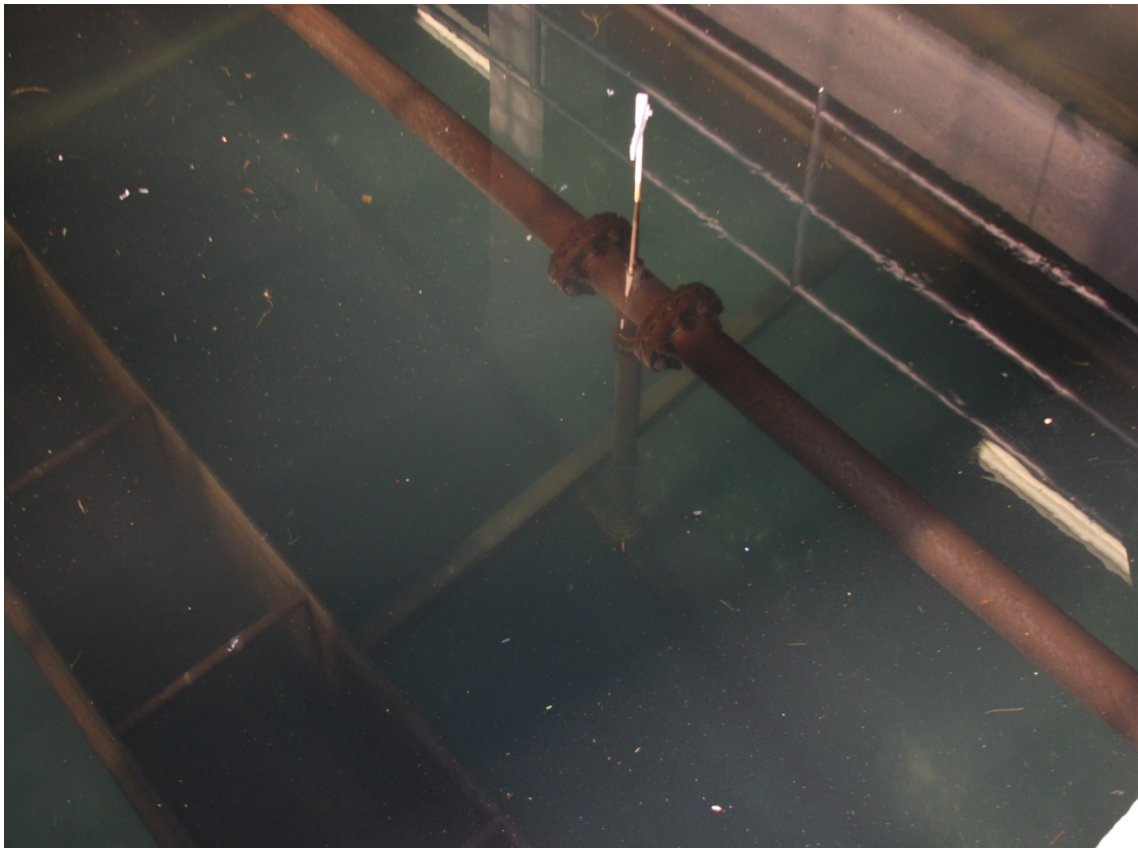
The photograph on the right shows a filter support bed under construction.

Air binding can also be caused by the water being cold and super-saturated with air. This air bubbles out as the water warms up. It is not possible for the operator to control this situation. If it happens, the filter must be backwashed more frequently to correct the filter air binding.

- ◆ Media loss is normal in any filter. Some are lost each time the filter is backwashed, especially if the filter surface wash is used. If a large amount of media is being lost, the method of washing should be inspected and corrected. The bed should not have to be expanded more than 20 percent during the backwash cycle. It may help to turn off the surface wash approximately two minutes before the end of the backwash. If this does not correct the problem, the filter troughs may have to be raised to prevent the excessive media loss.

Filter On-Line

After a well-operated filter backwash, the filter should be level and smooth with no cracks or mud balls at the surface. A good bed will appear to move laterally during the backwash and there will be no boils at the surface. The filter should clear up evenly cleaning. If some areas are not clean, there could be an under-drain problem.



Mudballs can be seen on the top layer of the media bed or during the backwash water cycle. Typically these will not flow over into the filter troughs.

Safe Drinking Water Act of 1974

(PL 93-523) as amended by:

- The Safe Drinking Water Act Amendments of 1986
- National Primary Drinking Water Regulations, 40 CFR 141
- National Interim Primary Drinking Water Regulations Implementation, 40 CFR 142
- National Secondary Drinking Water Regulations, 40 CFR 143

This is the primary Federal legislation protecting drinking water supplied by public water systems (those serving more than 25 people). The Environmental Protection Agency (**EPA**) is the lead agency and is mandated to set standards for drinking water. The EPA establishes national standards of which the states are responsible for enforcing.

The act provides for the establishment of primary regulations for the protection of the public health and secondary regulations relating to the taste, odor, and appearance of drinking water. Primary drinking water regulations, by definition, include either a maximum contaminant level (**MCL**) or, when a MCL is not economically or technologically feasible, a prescribed treatment technique which would prevent adverse health effects to humans.

An MCL is the permissible level of a contaminant in water that is delivered to any user of a public water system. Primary and secondary drinking water regulations are stated in 40 CFR 141 and 143, respectively. As amended in 1986, the EPA is required to set maximum contaminant levels for 83 contaminants deemed harmful to humans (with specific deadlines). It also has authority over groundwater. Water agencies are required to monitor water to ensure it meets standards.

The major elements of this law include: Questions 26-42

- The law updates the standard-setting process by focusing regulations on contaminants known to pose greater public health risks.
- It replaces the current law's demand for 25 new standards every three years with a new process based on occurrence, relative risk and cost-benefit considerations.
- It also requires the EPA to select at least five new candidate contaminants to consider for regulation every five years.
- The EPA is directed to require public water systems to provide customers with annual "Consumer Confidence Reports" in newspapers and by direct mail.
- The reports must list levels of regulated contaminants along with Maximum Contaminant Levels (MCLs) and Maximum Contaminant Level Goals (MCLGs), along with plainly worded definitions of both.
- The reports must also include a plainly worded statement of the health concerns for any contaminants for which there has been a violation, describe the utility's sources of drinking water and provide data on unregulated contaminants for which monitoring is required, including Cryptosporidium and radon.
- The EPA must establish a toll-free hot line customers can call to get additional information.
- The EPA is required to publish guidelines for states to develop water source assessment programs that delineate protection areas and assess contamination risks.
- The EPA is required to identify technologies that are affordable for small systems to comply with drinking water regulations.
- Technical assistance funds and Small System Technical Assistance Centers are authorized to meet the training and technical needs of small systems.
- States are authorized to grant variances for compliance with drinking water regulations for systems serving 3,300 or fewer persons.
- The EPA is required to publish certification guidelines for operators of community and nontransient noncommunity public water systems.
- States that do not have operator certification programs that meet the requirements of the guidelines will lose 20 percent of their SRLP grant.

- A source water petition program for voluntary, incentive-based partnerships among public water systems and others to reduce contamination in source water is authorized.
- The law establishes a new State Revolving Loan Fund (**SRLF**) of \$1 billion per year to provide loans to public water systems to comply with the new SDWA.
- It also requires states to allocate 15 percent of the SRLF to systems serving 10,000 or fewer people unless no eligible projects are available for loans.
- It also allows states to jointly administer SDWA and Clean Water Act loan programs and transfer up to 33 percent between the two accounts.
- States must ensure that all new systems have compliance capacity and that all current systems maintain capacity, or lose 20 percent of their SRLF grant.

Although the EPA will continue to provide policy, regulations and guidance, state governments will now have more regulatory flexibility allowing for improved communication between water providers and their local regulators. Increased collaboration will result in solutions that work better and are more fully supported by the regulated community. States that have a source water assessment program may adopt alternative monitoring requirements to provide permanent monitoring relief for public water systems in accordance with EPA guidance.

Water Quality Analysis

This section will cover daily lab analysis and some of the procedures. First, we will give a list, then a brief description of each analysis and how it influences the process. A daily chemistry lab sheet will show: Temperature, Turbidity, pH, Alkalinity, Hardness- Calcium and Magnesium, Total Solids, Iron, Fluoride, Free Chlorine, Combined Chlorine, Particle Count, Langelier Index, Log Removal and UV 254.

Temperature

A measure of the average kinetic energy of the particles in a sample of matter, expressed in terms of units or degrees designated on a standard scale. Depending on how cold or hot the water temperature is, chemical reactions in the process, such as coagulation, will be affected. We are all aware the colder the water, the longer the contact time; consideration must be made when setting the mixing speed due to the viscosity of the water. Disinfection is also influenced by temperature, depending on the amount of demand and contact required. This could increase the formation of THM.

Turbidity

Particles less than or about 1 to 10 μm in diameter (primarily colloidal particles) will not settle out by gravitational forces, therefore making them very difficult to remove. These particles are the primary contributors to the turbidity of the raw water causing it to be “cloudy”. The most important factor(s) contributing to the stability of colloidal particles is not their mass, but their surface properties. Lower turbidity improves disinfection and lessens the chance of Viruses and Giardia. This idea can be better understood by relating the colloidal particles large surface area to their small volume (**S/V**) ratio resulting from their very small size. In order to remove these small particles we must either filter the water or somehow incorporate gravitational forces such that these particles will *settle* out. In order to have gravity affect these particles we must somehow make them larger, somehow have them come together (agglomerate); or, in other words, somehow make them “*stick*” together, thereby increasing their size and mass. The two primary forces that control whether or not colloidal particles will agglomerate are:

Repulsive force

An electrostatic force called the “Zeta Potential” -

$$\zeta = \frac{4 \pi q d}{D}$$

Where:
 ζ = Zeta Potential
 q = charge per unit area of the particle
 d = thickness of the layer surrounding the shear surface through which the charge is effective

D = dielectric constant of the liquid

Attractive force

Force due to van der Waals forces

Van der Waals forces are weak forces based on a polar characteristic induced by neighboring molecules. When two or more nonpolar molecules, such as He, Ar, H₂, are in close proximity the nucleus of each atom will weakly attract electrons in the counter atom resulting, at least momentarily, in an asymmetrical arrangement of the nucleus.

This force, van der Waals force, is inversely proportional to the sixth power of the distance (1/d⁶) between the particles. As can clearly be seen from this relationship, decay of this force occurs exponentially with distance.

Ways to Measure Turbidity

- 1.) Jackson Candle Test
- 2.) Secchi Disk - a black and white disk divided like a pie in 4 quadrants about 6" in diameter.
- 3.) Turbidimeter - Light is passed through a sample. A sensitive photomultiplier tube at a 90° angle from the incident light beam detects the light scattered by the particles in the sample. The photomultiplier tube converts the light energy into an electrical signal, which is amplified and displayed on the instrument.
 - a.) *Units* - Nephelometric Turbidity Unit (**NTU**) or Formazin Turbidity Unit (**FTU**).

How to Treat Turbidity

Supercharge the water supply - By supercharging the water supply momentarily with a positive charge, we can upset the charge effect of the particles enough to reduce the Zeta potential (repulsive force) thereby allowing van der Waals forces (attractive forces) to take over.

By introducing aluminum (Al^{3+}) into the water in the form of Alum ($\text{Al}_2(\text{SO}_4)_3 \bullet 18\text{H}_2\text{O}$) we can accomplish the supercharging of the water. This is the *coagulation* part of the coagulation/flocculation process; flocculation follows coagulation. During the *flocculation* process the particles join together to form flocs; the larger the flocs, the faster they will settle within a clarifier.

Other chemical coagulants used are Ferric Chloride and Ferrous Sulfate. Alum works best in the pH range of natural waters, 5.0 - 7.5. Ferric Chloride works best at lower pH values, down to pH 4.5. Ferrous Sulfate works well through a range of pH values, 4.5 to 9.5.

During the coagulation process, charged hydroxy-metallic complexes are formed momentarily (i.e. $\text{Al}(\text{OH})_2^+$, $\text{Al}(\text{OH})_2^{1+}$ etc). These complexes are charged highly positive and therefore upset the stable negative charge of the target particles, thereby displacing the water layer surrounding the charged particle momentarily. This upset decreases the distance "d" in-turn decreasing the Zeta potential.

The particles are then able to get close enough together for van der Waals forces to take over and the particles begin to flocculate. The chemical reaction continues until the aluminum ions (Al^{+3}) reach their final form, $\text{Al}(\text{OH})_3$ (s), and settle out (note – the flocculated particles settle out separately from the precipitated $\text{Al}(\text{OH})_3$ (s)).

If too much alum is added then the opposite effect occurs, the particles form sub complexes with the Al^{+3} and gain a positive charge about them, and the particles re-stabilize.

The final key to obtaining good flocs is the added energy put into the system by way of rotating paddles in the flocculator tanks. By "**pushing**" (adding energy) the particles together we can aid in the flocculation process forming larger flocs.

It is important to understand that too much energy, i.e. rotating the paddles too fast, would cause the particles to shear (breakup), thereby reducing the size of the particles and would therefore increase the settling time in the clarifier.

pH

The pH of a sample of water is a measure of the concentration of hydrogen ions. The term pH was derived from the manner in which the hydrogen ion concentration is calculated - it is the negative logarithm of the hydrogen ion (H^+) concentration. What this means to those of us who are not mathematicians is that at higher pH, there are fewer free hydrogen ions, and that a change of one pH unit reflects a tenfold change in the concentrations of the hydrogen ion. For example, there are 10 times as many hydrogen ions available at a pH of 7 than at a pH of 8. The pH scale ranges from 0 to 14. A pH of 7 is considered to be neutral. Substances with pH of less than 7 are acidic; substances with pH greater than 7 are basic.

The pH of water determines the solubility (amount that can be dissolved in the water) and biological availability (amount that can be utilized by aquatic life) of chemical constituents such as nutrients (phosphorus, nitrogen, and carbon) and heavy metals (lead, copper, cadmium, etc.). For example, in addition to affecting how much and what form of phosphorus is most abundant in the water, pH may also determine whether aquatic life can use it. In the case of heavy metals, the degree to which they are soluble determines their toxicity. Metals tend to be more toxic at lower pH because they are more soluble.

Reasons for Natural Variation

Photosynthesis uses up dissolved carbon dioxide which acts like carbonic acid (H_2CO_3) in water. CO_2 removal, in effect, reduces the acidity of the water and so pH increases. In contrast, respiration of organic matter produces CO_2 , which dissolves in water as carbonic acid, thereby lowering the pH. For this reason, pH may be higher during daylight hours and during the growing season, when photosynthesis is at a maximum. Respiration and decomposition processes lower pH. Like dissolved oxygen concentrations, pH may change with depth in a lake, due again to changes in photosynthesis and other chemical reactions.

There is typically a seasonal decrease in pH in the lower layers of a stratified lake because CO_2 accumulates. There is no light for plants to fix CO_2 and decomposition releases CO_2 . Fortunately, lake water is complex; it is full of chemical "shock absorbers" that prevent major changes in pH. Small or localized changes in pH are quickly modified by various chemical reactions, so little or no change may be measured. This ability to resist change in pH is called buffering capacity. Not only does the buffering capacity control would-be localized changes in pH, but it controls the overall range of pH change under natural conditions. The pH scale may go from 0 to 14, but the pH of natural waters hovers between 6.5 and 8.5.

pH influences how well enhanced coagulation will remove TOC. It also has adverse effects to disinfection and the Distribution system.

Alkalinity

Alkalinity is a total measure of the substances in water that have "acid-neutralizing" ability. Don't confuse alkalinity with pH. pH measures the strength of an acid or base; alkalinity indicates a solution's power to react with acid and "buffer" its pH -- that is, the power to keep its pH from changing.

The main sources of natural alkalinity are rocks, which contain carbonate, bicarbonate, and hydroxide compounds. Borates, silicates, and phosphates may also contribute to alkalinity. Limestone is rich in carbonates, so waters flowing through limestone regions generally have high alkalinity -- hence it's good buffering capacity. Alkalinity has an impact on enhanced coagulation and SUVA. Without alkalinity corrosion would occur.

Hardness

Water hardness is a measure of the amount of calcium and magnesium salts in water. Calcium and magnesium enter water mainly through the weathering of rocks. The more calcium and magnesium in water, the harder the water will be.

Water hardness is usually expressed in milligrams per liter (mg/l) of dissolved calcium and magnesium carbonate. The term "hardness" comes from the fact that it is hard to get soapsuds 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. As a result, hard water can reduce the effectiveness of the cleaning process. This is also known to cause scale formation; it usually correlates with pH increase.

Total Dissolved Solids

Dissolved solids" refer to any minerals, salts, metals, cations or anions dissolved in water. Total dissolved solids (TDS) comprise inorganic salts (principally calcium, magnesium, potassium, sodium, bicarbonates, chlorides and sulfates) and some small amounts of organic matter that are dissolved in water.

TDS in drinking-water originate from natural sources, sewage, urban run-off, industrial wastewater, and chemicals used in the water treatment process, and the nature of the piping or hardware used to convey the water, i.e., the plumbing. In the United States, elevated TDS has been due to natural environmental features such as: mineral springs, carbonate deposits, salt deposits, and sea water intrusion, but other sources may include: salts used for road de-icing, anti-skid materials, drinking water treatment chemicals, stormwater and agricultural runoff, and point/non-point wastewater discharges.

In general, the total dissolved solids concentration is the sum of the cations (positively charged) and anions (negatively charged) ions in the water. Therefore, the total dissolved solids test provides a qualitative measure of the amount of dissolved ions, but does not tell us the nature or ion relationships. In addition, the test does not give us insight into the specific water quality issues, such as: Elevated Hardness, Salty Taste, or Corrosiveness. Therefore, the total dissolved solids test is used as an indicator test to determine the general quality of the water. The sources of total dissolved solids can include all of the dissolved cations and anions, but the following table can be used as a generalization of the relationship of TDS to water quality problems.

CATIONS COMBINED WITH CARBONATES CaCO ₃ , MgCO ₃ ETC	ASSOCIATED WITH HARDNESS, SCALE FORMATION, BITTER TASTE
CATIONS COMBINED WITH CHLORIDE NaCl, KCl	SALTY OR BRACKISH TASTE, INCREASE CORROSIVITY

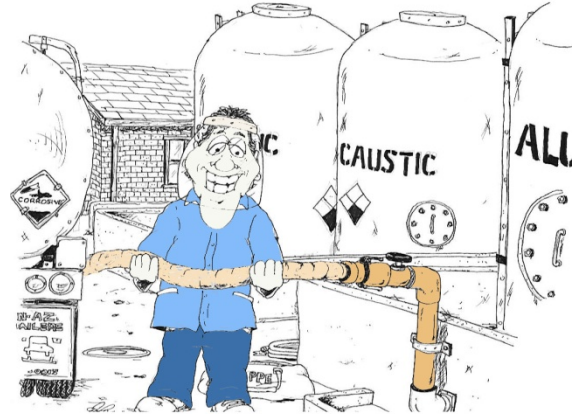
An elevated total dissolved solids (TDS) concentration is not a health hazard. The TDS concentration is a secondary drinking water standard and therefore is regulated because it is more of an aesthetic rather than a health hazard. An elevated TDS indicates the following:

- 1)The concentration of the dissolved ions may cause the water to be corrosive, have a salty or brackish taste, result in scale formation, and interfere and decrease efficiency of hot water heaters; and
- 2)Many contain elevated levels of ions that are above the Primary or Secondary Drinking Water Standards, such as: an elevated level of nitrate, arsenic, aluminum, copper, lead, etc.

Iron

Iron is part of the Secondary Rules. Iron is one of the most troublesome elements in water supplies. Making up at least 5 percent of the earth's crust, iron is one of the earth's most plentiful resources. Rainwater as it infiltrates the soil and underlying geologic formations dissolves iron. It is understandable, therefore, that most groundwater supplies contain some measurable amount of iron. Although present in water, iron is seldom found at concentrations greater than 10 milligrams per liter (mg/l) or 10 parts per million. However, *as little as 0.3 mg/l can cause water to turn a reddish brown color.* Iron stains and contaminates anything it contacts. The resulting stains are usually yellowish-brown to reddish-brown, but may be gray to black in the presence of some organics. *Iron may also cause undesirable odors and tastes in water.*

Iron is mainly present in water in various forms but the two most common forms are either the soluble ferrous iron or the insoluble ferric iron. Water containing ferrous iron is clear and colorless because the iron is completely dissolved. When exposed to air or the atmosphere, the water turns cloudy and a reddish brown substance begins to form. This sediment is the oxidized or ferric form of iron that will not dissolve in water. Manganese is frequently found with and is similar to iron but forms a brownish-black precipitate and stains. Manganese is less commonly found in groundwater than iron, rarely found alone in a water source, and generally found with dissolved iron.



Fluoride

Fluoride exists naturally in water sources and is derived from fluorine, the thirteenth most common element in the Earth's crust. It is well known that fluoride helps prevent and even reverse the early stages of tooth decay. The primary rule MCL is 4.0 mg/L.

Free and Combined Residual

When chlorine is added to water, some of the chlorine reacts first with organic materials and metals in the water and is not available for disinfection (this is called the *chlorine demand* of the water). The remaining chlorine concentration after the chlorine demand is accounted for is called *total chlorine*. Total chlorine is further divided into: 1) the amount of chlorine that has reacted with nitrates and is unavailable for disinfection which is called *combined chlorine* and, 2) the *free chlorine*, which is the chlorine available to inactivate disease-causing organisms, and thus a measure to determine the potability of water.

Particle Count

Particle counters are instruments currently used in research that have the capacity to count numbers and determine sizes of particles in suspension. Research has shown that reducing the amount of particulate matter in potable water reduces the risk of human pathogens such as *Cryptosporidium parvum* entering drinking water supplies.

Since particle counters have several advantages over turbidity meters, such as a higher sensitivity to changes in water quality at low turbidities (below 0.1 NTU), a higher sensitivity to changes associated with larger particle sizes, and a particle-sizing capability, they may someday replace turbidity meters. However, turbidity meters are the preferred monitoring mechanism for process control of particulate matter in potable water at this time.

Langelier Index

The Langelier Saturation Index is a means of evaluating water quality data to determine if the water has a tendency to form a chemical scale. In order to use this index, the following laboratory analysis is needed: pH, conductivity, total dissolved solids, alkalinity, and total hardness. In manipulating the data, the actual pH of the water is compared to the theoretical pH (pHs) based on the chemical analysis.

The Saturation Index (SI) $SI = pH - pHs$

The Saturation Index is typically either negative or positive and rarely 0. A Saturation Index of zero indicates that the water is “balanced” and is less likely not to cause scale formation. A negative SI suggests that the water would be undersaturated with respect to carbonate equilibrium and the water may be more likely to have a greater corrosive potential.

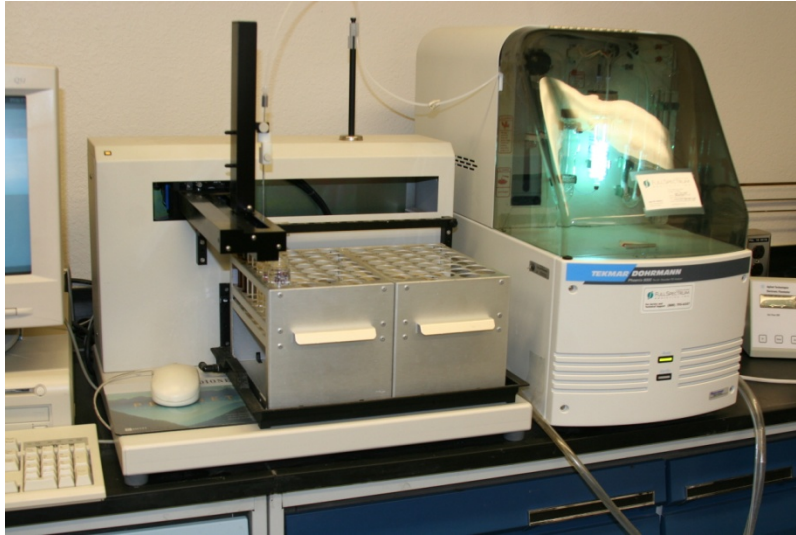
A positive SI suggests that water may be scale forming. The scale, typically a carbonate residue, could clog or reduce the flow in pipes, cause buildup on hot water heaters, impart an alkali taste to the water, reduce the efficiency of the water heaters, and cause other aesthetic problems.

Saturation Index	Description	General Recommendation
- 5	Severe Corrosion	Treatment Recommended
- 4	Severe Corrosion	Treatment Recommended
- 3	Moderate Corrosion	Treatment Recommended
- 2	Moderate Corrosion	Treatment May Be Needed
-1	Mild Corrosion	Treatment May Be Needed
-0.5	None- Mild Corrosion	Probably No Treatment
0	Near Balanced	No Treatment
0.5	Some Faint Coating	Probably No Treatment
1	Mild Scale Coating	Treatment May Be Needed
2	Mild to Moderate Coatings	Treatment May Be Needed
3	Moderate Scale Forming	Treatment Advisable
4	Severe Scale Forming	Treatment Advisable

Please Note- SI Index is not a reliable means of evaluating corrosion potential, but it can be used as a guide.

UV 254

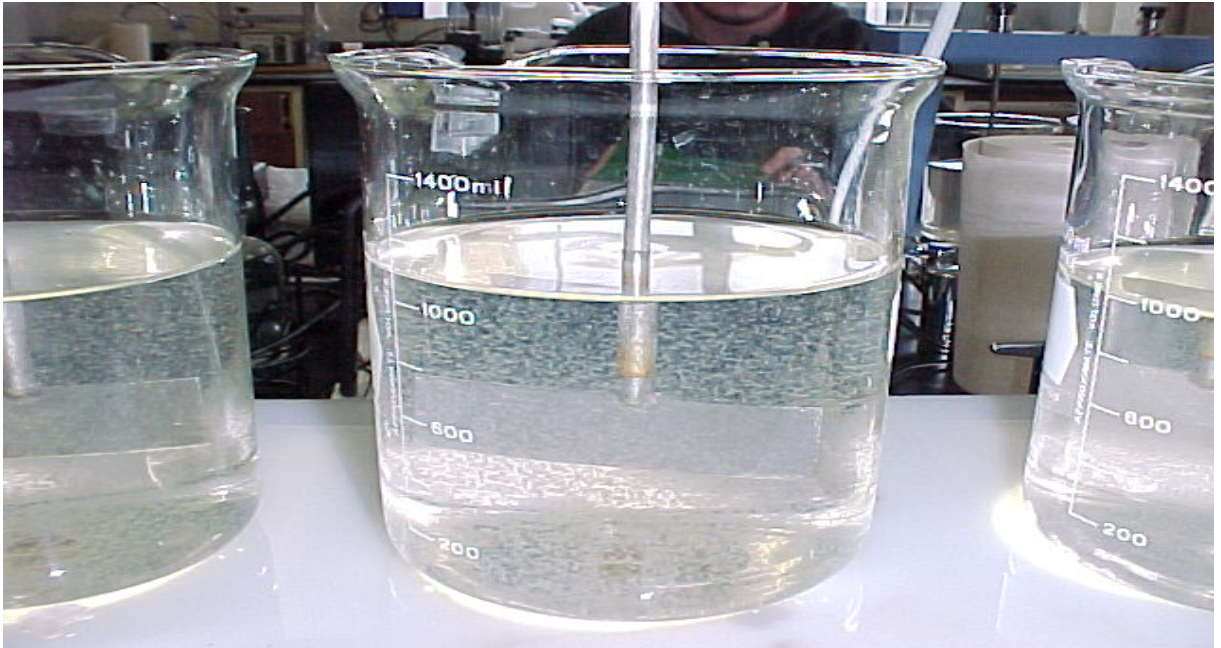
Total organic carbon (**TOC**) is an important indicator of water quality in drinking water supply systems. Prescribed chlorination rates are often based on TOC levels, and levels of disinfection byproducts (**DBP**) can be subsequently approximated. Unfortunately, TOC is difficult to measure, and some water utilities rely on the more easily measured absorbance of ultraviolet light (specifically at a wavelength of 254 nm, abbreviated UV-254) as a surrogate indicator of organic content. For daily or weekly operating purposes, measurements of UV-254 can provide inexpensive and meaningful prescriptive guidance for disinfection processes.



Water Treatment labs use unit like this to measure total organic carbon (TOC).

Required EPA Information

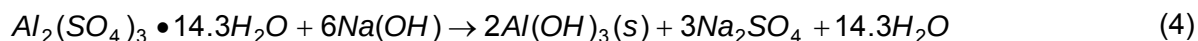
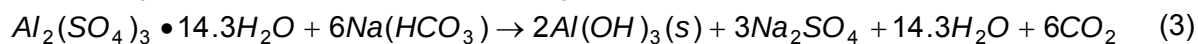
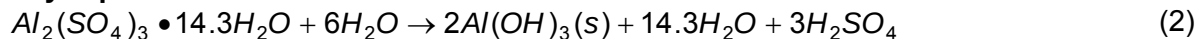
- EPA is directed to require public water systems to provide customers with annual **"Consumer Confidence Reports"** in newspapers and by direct mail.
- The reports must list levels of regulated contaminants along with Maximum Contaminant Levels (**MCLs**) and Maximum Contaminant Level Goals (**MCLGs**), along with plainly worded definitions of both.
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- EPA must establish a toll-free hot line customers can call to get additional information.
- EPA is required to publish guidelines for states to develop water source assessment programs that delineate protection areas and assess contamination risks.
- EPA is required to identify technologies that are affordable for small systems to comply with drinking water regulations.



Jar testing is used to determine what chemical dosage is best.

Jar Testing

Key Equations

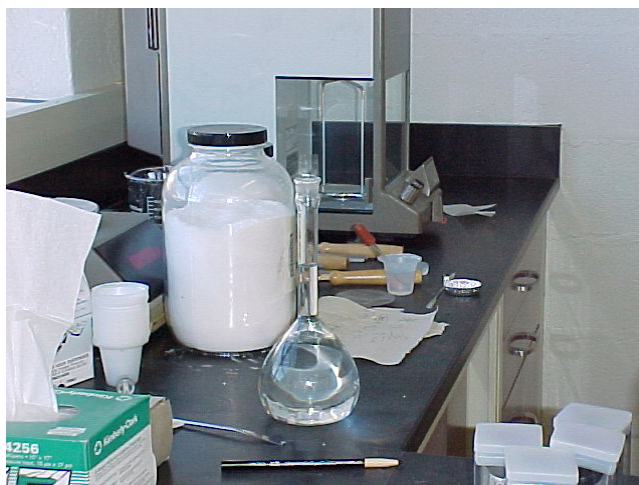


Apparatus

- 1) Jar Test Apparatus
- 2) 6 1500 mL Beakers
- 3) pH meter
- 4) Pipettes
- 5) Conductivity Meter
- 6) Turbidimeter

Procedure

- 1) Make up a 10-g/L solution of alum.
- 2) Make up a 0.1 N solution of NaOH (buffer). ($Na^{+1} = 23 \text{ mg/mmol}$, $O^{-2} = 16 \text{ mg/mmol}$, $H^{+} = 1 \text{ mg/mmol}$)
- 3) Fill each of the six 1500 mL beakers with one-liter of river water.
- 4) Measure the temperature and conductivity.
- 5) Measure the initial pH
- 6) Add alum and NaOH solutions in equal portions as specified by instructor.
- 7) Mixing protocol:
 - a. rapid mix - 1 minute (100 rpm)
 - b. slow mix - 15 minutes (20 rpm)
 - c. off, settling - 30 minutes
- 8) Measure final turbidity. Take the sample from the center, about 2" down for each one liter sample. Be careful not to disturb the flocs that have settled.
- 9) Measure final pH



Alum solution being prepared in the lab before actual application in the process.

Information to be Recorded

Initial Turbidity = ? NTU
- 0.1 N

Alum - g/L

Buffer

[illegible]

Preparing Polymers for the Jar Test

A successful Jar Test is very reliant upon the proper preparation of the polymers being tested. Dilution technique is especially critical, since it involves compactly coiled large molecules in emulsions, prior to activation. The polymer must be uncoiled to provide maximum contact with the colloidal particles to be flocculated. If the following procedures are not followed, the Jar Test results will be very unreliable.

Required Equipment:

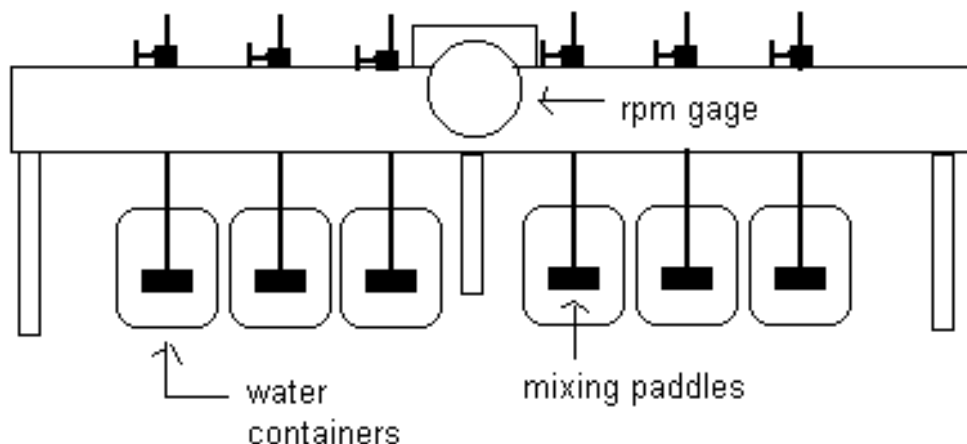
1. 250 mL bottles with lids.
2. High speed hand mixer (for emulsion polymers).
3. Syringes (1cc, 5cc, 10cc).
4. 250 and 500 mL beakers.
5. Water (it is recommended that the makedown water from the plant be used).
6. Graduated cylinder (100 mL).

Emulsion Polymers (Prepare 1.0% solution.)

1. Add 198 mL of water to a beaker.
2. Insert Braun mixer into water and begin mixing.
3. Using a syringe, inject 2 mL of neat polymer into vortex.
4. Mix for 20 seconds. Do not exceed 20 seconds!
5. Allow dilute polymer to age for at least 20 minutes, but preferably overnight.
Prepare 0.1% solution.
6. Add 180 mL of water to 250 mL bottle.
7. Add 20 mL of 1.0% polymer solution.
8. Shake vigorously for at least one minute.

Solution Polymers and Inorganics (Prepare a 1.0% solution.)

1. Add 198 mL of water to 250 mL bottle.
2. Using a syringe, add 2 mL of neat product to bottle.
3. Shake vigorously for at least 1 minute.
4. Prepare 0.1% solution.
5. Add 180 mL to 250 mL bottle.
6. Add 20 mL of 1 % solution.
7. Shake vigorously for at least one minute.



Potassium Permanganate Jar Test

Potassium Permanganate has been used for a number of years in both water & wastewater treatment. KMnO_4 is a strong oxidizer which can be used to destroy many organic compounds of both the natural and man-made origin. KMnO_4 is also used to oxidize iron, manganese and sulfide compounds and other taste and odor producing substances usually due to the presence of very small quantities of secretions given off by microscopic algae, which develop on the surface waters and on beds of lakes and rivers under certain conditions of temperature and chemical composition.

KMnO_4 must be used with caution as this material produces an intense purple color when mixed with water. As the permanganate ion is reduced during its reaction with compounds that it oxidizes, it changes color from purple, to yellow or brown. The final product formed is manganese dioxide (MnO_2) an insoluble precipitate that can be removed by sedimentation and filtration.

I must caution you that all KMnO_4 applied must be converted to manganese dioxide (MnO_2) form prior to filtration. If it is not all converted and is still purple or pink, it will pass through the filter into the clearwell or distribution system. This may cause the customer to find pink tap water, or the reaction may continue in the system and the same conditions as exist with naturally occurring manganese may cause staining of the plumbing fixtures.

Stock Solutions

(Strong Stock Solution)

5 grams potassium permanganate dissolved in 500 ml distilled water.

(Test Stock Solution)

4 ml strong stock solution thoroughly mixed in 100 ml distilled water.

Each 5 ml of the test stock solution added to a 2000 ml sample equals 1 mg/l.

Jar Testing Example

If you have a six position stirrer:

Using a graduated cylinder, measure 2000 ml of the sample to be tested into each of the six beakers. Dose each beaker to simulate plant practices in pre-treatment, pH adjustment, coagulant, - etc. Do not add carbon or chlorine. Using a graduated pipette, dose each beaker with the test stock solution in the following manner.

Jar #	KMnO_4	ml	KMnO_4 mg/l	Color
1	0.50		0.10	no pink
2	0.75		0.15	no pink
3	1.00		0.20	no pink
4	1.25		0.25	no pink
5	1.50		0.30	pink
6	1.75		0.35	pink

Stir the beakers to simulate the turbulence where the KMnO_4 is to be added and observe the color change. As the iron and manganese begin to oxidize, the sample will turn varying shades of brown, indicating the presence of oxidized iron and or manganese. Samples which retain a brown or yellow color indicate that the oxidation process is incomplete and will require a higher dosage of KMnO_4 .

The end point has been reached when a pink color is observed and remains for at least 10 minutes. In the preceding table, a pink color first developed in beaker #5 which had been dosed with 1.5 ml/ 0.3 mg/l. If the first jar test does not produce the correct color change, continue with increased dosages.

When applying potassium permanganate to raw water, care must be taken not to bring pink water to the filter unless you have "**greensand**". Also, permanganate generally reacts more quickly at pH levels above 7.0.

Quick Test

A quick way to check the success of a KMnO_4 application is by adding 1.25 ml of the test stock solution to 1000 ml finished water. If the sample turns brown there is iron or manganese remaining in the finished water. If the sample remains pink, oxidation is complete. With proper application, potassium permanganate is an extremely useful chemical treatment.

As well as being a strong oxidizer for iron and manganese, KMnO_4 used as a disinfectant in pre-treatment could help control the formation of trihalomethanes by allowing chlorine to be added later in the treatment process or after filtration. Its usefulness also extends to algae control, as well as many taste/odor problems.

To calculate the dosage of KMnO_4 for iron and manganese removal here is the formula to use.

$$\text{KMnO}_4 \text{ Dose, mg/l} = 0.6(\text{iron, mg/l}) + 2.0(\text{Manganese, mg/l})$$

Example:

Calculate the KMnO_4 dose in mg/l for a water with 0.4 of iron. The manganese concentration is 1.2 mg/l.

Known Unknown

Iron, mg/l = 0.4 mg/l KMnO_4 Dose, mg/l

Manganese, mg/l = 1.2 mg/l

Calculate the KMnO_4 dose in mg/l.

$$\begin{aligned}\text{KMnO}_4 \text{ Dose, mg/l} &= 0.6(\text{Iron, mg/l}) + 2.0(\text{Manganese, mg/l}) \\ &= 0.6(0.4 \text{ mg/l}) + 2.0(1.2 \text{ mg/l}) \\ &= 2.64 \text{ mg/l}\end{aligned}$$

Note: The calculated 2.64 mg/l KMnO_4 dose is the minimum dose. This dose assumes there are no oxidizable compounds in the raw water. Therefore, the actual dose may be higher. Jar testing should be done to determine the required dose.





Iron is mainly present in water in various forms but the two most common forms are either the soluble ferrous iron or the insoluble ferric iron. Water containing ferrous iron is clear and colorless because the iron is completely dissolved. When exposed to air or the atmosphere, the water turns cloudy and a reddish brown substance begins to form. This sediment is the oxidized or ferric form of iron that will not dissolve in water. Manganese is frequently found with and is similar to iron but forms a brownish-black precipitate and stains. Manganese is less commonly found in groundwater than iron, rarely found alone in a water source, and generally found with dissolved iron.

Alkalinity

Introduction

Alkalinity of a water is its acid-neutralizing capacity. It is the sum of all the titratable bases. The measured value may vary significantly with the end-point pH used. Alkalinity is a measure of an aggregate property of water and can be interpreted in terms of specific substances only when the chemical composition of the sample is known.

Alkalinity is significant in many uses and treatments of natural waters and wastewaters. Because the alkalinity of many surface waters is primarily a function of carbonate, bicarbonate, and hydroxide content, it is taken as an indication of the concentration of these constituents. The measured values also may include contributions from borates, phosphates, silicates or other bases if these are present. Alkalinity in excess of alkaline earth metal concentrations is significant in determining the suitability of a water for irrigation. Alkalinity measurements are used in the interpretation and control of water and wastewater treatment processes.

Titration Method

a. Principle

Hydroxyl ions present in a sample as a result of dissociation or hydrolysis of solutes react with additions of standard acid. Alkalinity thus depends on the end-point pH used.

b. Reagents

- i) Standard Hydrochloric Acid – 0.02 N.
- ii) Methyl Orange Indicator – Dissolve 0.1 g of methyl orange in distilled water and dilute to 1 liter.
- iii) Sodium carbonate solution, 0.02 N : Dry 3 to 5 g primary standard Na_2CO_3 at 250°C for 4 h and cool in a desiccator. Weigh 1.03 gm. (to the nearest mg), transfer to a 1-L volumetric flask, fill flask to the mark with distilled water, and dissolve and mix reagent. Do not keep longer than 1 week.

c. Procedure

Titrate over a white surface 100 ml of the sample contained in a 250-ml conical flask with standard hydrochloric acid using two or three drops of methyl orange Indicator. (**NOTE** – If more than 30 ml of acid is required for the titration, a smaller suitable aliquot of the sample shall be taken.)

d. Calculation

Total alkalinity (as CaCO_3), mg/l = $10 V$ or
$$\frac{N \times V \times 50 \times 1000}{\text{Sample Amount}}$$

T.A. (as CaCO_3) = $\frac{N \times V \times 50 \times 1000}{\text{Sample Amount}}$

Where N = Normality of HCl used

V = volume in ml of standard hydrochloric acid used in the titration.

Alkalinity to Phenolphthalein

The sample is titrated against standard acid using phenolphthalein indicator.

a. Reagents

- i) Phenolphthalein Indicator Solution :

Dissolve 0.1 g of phenolphthalein in 60 ml of ETHANOL and dilute with Distilled water to 100 ml.

ii) Standard hydrochloric Acid – 0.02 N.

b. Procedure

Add 2 drops of phenolphthalein indicator solution to a sample of suitable size, 50 or 100 ml, in a conical flask and titrate over a white surface with standard hydrochloric acid.

c. Calculation

$$\text{Alkalinity to phenolphthalein (as CaCO}_3\text{), mg/l} = \frac{1000 V_1}{V_2}$$

Where

V_1 = volume in ml of standard hydrochloric acid used in the titration , and

V_2 = Volume in ml of the sample taken for the test.

Caustic Alkalinity

a. General

Caustic alkalinity is the alkalinity corresponding to the hydroxides present in water and is calculated from total alkalinity (T) and alkalinity to phenolphthalein (P).

b. Procedure Determine total alkalinity and alkalinity to phenolphthalein and calculate caustic alkalinity as shown in Table below. Result of Titration Caustic Alkalinity or Hydroxide Alkalinity as CaCO_3 Carbonate Alkalinity as CaCO_3 Bicarbonate Concentration as CaCO_3 Result of Titration	Caustic Alkalinity or Hydroxide Alkalinity as CaCO_3	Carbonate Alkalinity as CaCO_3	Bicarbonate Concentration as CaCO_3
P=0	0	0	0
P<1/2T	0	2P	T-2P
P=1/2T	0	2P	0
P>1/2T	2P-T	2(T-P)	0
P=T	T	0	0

The alkalinity of water is a measure of its capacity to neutralize acids. The alkalinity of natural water is due to the salts of carbonate, bicarbonate, borates, silicates and phosphates along with the hydroxyl ions in free state. However the major portion of the alkalinity in natural waters is caused by hydroxide, carbonate and bicarbonates which may be ranked in order of their association with high pH values. Alkalinity values provide guidance in applying proper doses of chemicals in water and waste water treatment processes, particularly in coagulation and softening.

Alkalinity (total)

References: ASTM D 1067-92, Acidity or Alkalinity of Water.

APHA Standard Methods, 19th ed., p. 2-26, method 2320B (1995).

EPA Methods for Chemical Analysis of Water and Wastes, method 310.1 (1983).

The alkalinity of water is a measurement of its buffering capacity or ability to react with strong acids to a designated pH. Alkalinity of natural waters is typically a combination of bicarbonate, carbonate and hydroxide ions. Sewage and wastewaters usually exhibit higher alkalinities either due to the presence of silicates and phosphates or to a concentration of the ions from natural waters.

Alkalinity inhibits corrosion in boiler and cooling waters and is therefore a desired quality which must be maintained. It is also measured as a means of controlling water and wastewater treatment processes or the quality of various process waters. In natural waters, excessive alkalinity can render water unsuitable for irrigation purposes and may indicate the presence of industrial effluents. The Titrimetric Method. CHEMetrics' tests determine total or "M" alkalinity using an acid titrant and a pH indicator. The end point of the titration occurs at pH 4.5. Results are expressed as ppm (mg/L) CaCO_3 .

Hardness (calcium)

Reference: West, T. S., DSC, Ph.D., Complexometry with EDTA and Related Reagents, 3rd ed., p. 46, 164 (1969).

Originally described as water's capacity to precipitate soap, hardness is one of the most frequently determined qualities of water. It is a composite of the calcium, magnesium, strontium and barium concentrations in a sample. The current practice is to assume total hardness refers to the calcium and magnesium concentrations only.

Completely dehardened water, resulting from sodium zeolite or other suitable ion exchange treatment, is required for various processes-including power generation, printing and photo finishing, pulp and paper manufacturing, and food and beverage processing. Hard water can cause scale formation on heat exchange surfaces resulting in decreased heat transfer and equipment damage.

The Titrimetric Method. This method is specific for calcium hardness. The EGTA titrant in alkaline solution is employed with zincon indicator. Results are expressed as ppm (mg/L) CaCO_3 .

Shelf-life. 8 months. Although the reagent itself is stable, the end point indicator has a limited shelf-life. We recommend stocking quantities that will be used within 7 months.

Hardness (total)

References: Colorimetric-Calcichrome chemistry--Method developed by CHEMetrics, Inc.

Titrimetric--APHA Standard Methods, 19th ed., p. 2-36, method 2340 C (1995).

EPA Methods for Chemical Analysis of Water and Wastes, method 130.1 (1983).



The alkalinity of water is a measure of its capacity to neutralize acids. The alkalinity of natural water is due to the salts of carbonate, bicarbonate, borates, silicates and phosphates along with the hydroxyl ions in free state. However the major portion of the alkalinity in natural waters is caused by hydroxide, carbonate and bicarbonates which may be ranked in order of their association with high pH values. Alkalinity values provide guidance in applying proper doses of chemicals in water and waste water treatment processes, particularly in coagulation and softening.

Total Dissolved Solids (Filterable)

The dissolved (Filterable) solids can be determined from the difference between the residue on evaporation and total suspended solids, but if the dissolved solids content is low and the suspended solids high, a direct determination is better. It is preferable to adopt the centrifugal method of separating suspended matter so that a sufficiently large volume of separated liquid is available for the determination.

Principle

A known volume of filtered sample is evaporated and dried in a weighed dish at 105°C to constant weight the increase in weight over the empty dish represents the dissolved solids.

Apparatus

1. Evaporating dishes, 50, 100 mL capacity (Preferably porcelain or silica).
2. Pipettes 25, 50 ml capacity
3. Water bath & Oven
4. Balance to weigh up to 4th decimal.

Procedure

The known volume (V) of filtered sample in a previously ignited and weighed basin (W_1). Evaporate to dryness on a steam bath and further dry at 105°C for one or two hours in an oven. Cool in dessicator and weight (W_2). Repeat by further heating for 15 minutes and cooling until successive results do not differ by more than about 0.4 mg.

Calculation

$$\text{Dissolved solids mg/L} = \frac{(W_2 - W_1) \times 1000}{V}$$

Where

W_2 = Weight of residue and dish

W_1 = Weight of empty and dry dish

V = Weight of sample



Lab equipment used for determining Total Dissolved Solids.



Dissolved solids" refer to any minerals, salts, metals, cations or anions dissolved in water. Total dissolved solids (TDS) comprise inorganic salts (principally calcium, magnesium, potassium, sodium, bicarbonates, chlorides and sulfates) and some small amounts of organic matter that are dissolved in water.

TDS in drinking-water originate from natural sources, sewage, urban run-off, industrial wastewater, and chemicals used in the water treatment process, and the nature of the piping or hardware used to convey the water, i.e., the plumbing. In the United States, elevated TDS has been due to natural environmental features such as: mineral springs, carbonate deposits, salt deposits, and sea water intrusion, but other sources may include: salts used for road de-icing, anti-skid materials, drinking water treatment chemicals, stormwater and agricultural runoff, and point/non-point wastewater discharges.

Turbidity

Suspension of particles in water interfering with passage of light is called turbidity. Turbidity is caused by a wide variety of suspended matter which range in size from colloidal to coarse dispersions depending upon the degree of turbulence; it also ranges from pure inorganic substances to those that are highly organic in nature. Turbid waters are undesirable from aesthetic point of view in drinking water supplies and may also affect products in industries. Turbidity is measured to evaluate the performance of water treatment plant.

Principle

Turbidity can be measured either by its effect on the transmission of light which is termed as Turbidimetry or by its effect on the scattering of light which is termed as Nephelometry. A Turbidimeter can be used for samples with moderate turbidity and a Nephelometer for samples with low turbidity. The higher the intensity of scattered light, the higher the turbidity.

Interference

Color is the main source of interference in the measurement of turbidity.

Apparatus : Turbidimeter or Nephelometer.

Reagents

1. Solution I: Dissolve 1.0 gm Hydrazine Sulfate and dilute to 100 mL.
2. Solution II: Dissolve 10.0 gm Hexamethylene tetramine and dilute to 100 mL.
3. Mix 5 mL of I with 5 mL of II. Allow to stand for 24 hrs. at $25 \pm 3^\circ\text{C}$ and dilute to 100 mL. This solution (III) will have turbidity of 400 units (N.T.U.)
4. Standard turbidity suspension: Dilute 10 mL of solution III as prepared above to 100 mL to have solution of the turbidity of 40 units. (N.T.U.)

Procedure

1. Prepare calibration curve in the range of 0-400 units by carrying out appropriate dilutions of solutions III and IV above taking readings on turbidimeter.
2. Take sample or a suitably diluted aliquot and determine its turbidity either by visual comparison with the diluted standards or by reading on turbidimeter.
3. Read turbidity from the standard curves and apply correction due to dilution, if necessary.
4. Report the readings in turbidity units.



Floating clumps of floc in the flocculation compartment.



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.



Standard Operating Procedure for the Determination of Total Organic Carbon in Water

1.0 Scope and Application

This method is used to determine total organic carbon (TOC) in water. A concentration of 0.01 mg/L can be measured by some instruments if scrupulous attention is given to minimizing sample contamination and method background.

2.0 Summary of Method

There are two different ways to determine total organic carbon (TOC). The first way is by the TOC mode. The inorganic carbon (IC) is first removed from the sample by acidification and sparging and then the organic carbon (OC) is oxidized to carbon dioxide (CO_2) by sodium persulfate in the presence of ultraviolet light. The CO_2 produced is purged from the sample, dried, and transferred with a carrier gas to a non-dispersive infrared (NDIR) analyzer that is specifically tuned to the absorptive wavelength of CO_2 . The instrument's microprocessor converts the detector signal to organic carbon concentrations in mg/L based on stored calibration data. The second way is TOC by difference. This is just total carbon (TC) minus inorganic carbon. The TC is all the carbon in the sample, both IC and OC. The IC is determined in the same manner as the in TOC mode.

3.0 Definitions

3.1 The definitions and purposes below are specific to this method, but have been conformed to common usage as much as possible.

3.2 Liter: L

Milliliter: mL

Grams: g

Total Organic Carbon: TOC

Total Carbon: TC

Inorganic Carbon: IC

Organic Carbon: OC

Carbon Dioxide: CO_2

Non dispersive infrared: NDIR

Dissolved organic carbon: DOC

3.3 May: This action, activity, or procedural step is neither required nor prohibited. **May not:** This action, activity, or procedural step is prohibited. **Must:** This action, activity, or procedural step is required. **Shall:** This action, activity, or procedural step is required. **Should:** This action, activity, or procedural step is suggested, but not required

4.0 Interferences

4.1 Removal of carbonate and bicarbonate by acidification and purging with purified gas results in the loss of volatile organic substances. The volatiles also can be lost during sample blending, particularly if the temperature is allowed to rise. Another important loss can occur if large carbon-containing particles fail to enter the needle used for injection.

Filtration, although necessary to eliminate particulate organic matter when only dissolved organic carbon (DOC) is to be determined, can result in loss or gain of DOC, depending on the physical properties of the carbon-containing compounds and adsorption and desorption of the carbon matter on the filter. Avoid contaminated glassware, plastic containers, and rubber tubing. Insufficient acidification will result in incomplete release of CO_2 .

4.2 The intensity of the ultraviolet light reaching the sample matrix may be reduced by highly turbid samples or with aging of the ultraviolet source, resulting in sluggish or incomplete oxidation. Large organic particles or very large or complex organic molecules such as tannins, lignins, and humic acid may be oxidized slowly because persulfate oxidation is rate-limited. However, oxidation of many large biological molecules such as proteins and monoclonal antibodies proceeds rapidly.

4.3 Persulfate oxidation of organic molecules is slowed in samples containing sufficient concentrations of chloride by the preferential oxidation of chloride; at concentrations above 0.05% chloride, oxidation of organic matter may be inhibited. To remove this interference add mercuric nitrate to the persulfate solution in UV-persulfate instruments, or extend reaction time and/or increase amount of persulfate solution in heated persulfate instruments.

4.4 With any organic carbon measurement, contamination during sample handling and treatment is a likely source of interference. This is especially true of trace analysis. Take extreme care in sampling, handling and analysis of samples below 1 mg/L TOC.

5.0 Safety

5.1 This method does not address all safety issues associated with its use. The laboratory is responsible for maintaining a safe work environment and a current awareness file of OSHA regulations regarding the safe handling of the chemicals specified in this method. A reference file of material safety data sheets for each chemical used in this method should be available to all personnel involved in these analyses.

5.2 Each chemical should be treated as a potential health hazard. Exposure to these chemicals should be reduced to the lowest possible level. It is suggested that the laboratory perform personal hygiene monitoring of each analyst using this method and that the results of this monitoring be made available to the analyst.

5.3 Unknown samples may contain high concentrations of volatile compounds. Sample containers should be opened in a hood and handled with gloves to prevent exposure.

6.0 Equipment and Supplies

Note: Brand names, suppliers, and part numbers are cited for illustrative purposes only. No endorsement is implied. Equivalent performance may be achieved using equipment and materials other than those specified here, but demonstration of equivalent performance that meets the requirements of this method is the responsibility of the laboratory.

6.1 Tekmar-Dohrman Phoenix 8000 TOC uv-persulfate analyzer or other comparable brand with autosampler.

6.2 0-14 pH paper.

6.3 10 ml syringe.

6.4 0.45 micron glass fiber filters.

6.5 125 ml sample bottles:

6.6 Autosampler vials: 40 mL amber glass vials with Teflon-faced septa. These vials should be washed with laboratory detergent and thoroughly rinsed with tap water followed by reverse osmosis water and allowed to dry. The vials should then be rinsed with acetone followed by hexane and allowed to dry. Finally, the vials should be dried in the drying oven used for drying vials used for the analysis of volatile organic compounds.

7.0 Reagents and Standards

7.1 Reagent water: ultrapure from the spectroscopy lab.

7.2 21% phosphoric acid: add 37 ml of 85% phosphoric acid to 188 ml of reagent water. Always add acid to water.

7.3 LabChem Inc. Catalog number LC12910-1 Organic carbon stock solution. 1000 parts per million. Primary standard grade. 1mL=1mg. If it is prepared in the laboratory, it should be preserved by adding phosphoric acid until the pH is <2.

This stock standard solution is used with drinking water samples.

7.4 Inorganic carbon stock solution: Dissolve 4.4122 g anhydrous sodium carbonate, in reagent water, add 3.4970 g anhydrous sodium bicarbonate and dilute to 1000 mL; 1mL=1mg carbon. Keep tightly stoppered. Do not acidify. Used for analysis of surface waters in determining TOC by difference. To make the standards use 4 mL to make 20 ppm, 20 mL for 100 ppm, and 40 mL for 200 ppm. There are different methods in the Phoenix 8000 that can be used. Choose the one that best suits the samples involved.

7.5 Carrier gas. This lab uses nitrogen, CO₂-free and containing less than 1 ppm hydrocarbon.

7.6 Purging gas. Any gas free of CO₂ and hydrocarbons. This lab uses nitrogen.

7.7 Persulfate solution. Acros. 98+ %. Add 25 g of sodium persulfate to 213 mL of reagent water and add 9 mL of phosphoric acid.

8.0 Sample Collection, Preservation, and Storage

8.1 If possible, rinse bottles with sample before filling.

8.2 Collect and store samples in glass bottles protected from sunlight and seal with TFE-backed septa. Preferably use thick silicone rubber-backed TFE septa with open ring caps to produce a positive seal. Before use, wash bottles with laboratory detergent, rinse thoroughly with tap and reverse osmosis water and allow to dry. Then rinse with acetone and hexane and dry in the oven used for drying vials used for analysis of volatile organic carbon compounds. Analyze a

bottle blank with each set of sample bottles to determine effectiveness or necessity of cleaning. This can be done by filling a sample bottle (bottle blank) with reagent water in the laboratory when the sample containers are shipped out and holding the sample bottle at 0-4 degrees C until the associated samples are analyzed.

8.3 Drinking water-related samples must either be analyzed or must be acidified to achieve pH <2.0 by addition of minimal phosphoric or sulfuric acid as soon as practical after sampling, not to exceed 24 hours. Check pH before analysis by using a stirring rod to dip in the container and then touch it to the pH paper. If the sample is a groundwater sample, it should not be acidified because there would be a loss of inorganic carbon from the sample in the form of CO₂. Regardless of what is being analyzed, all samples must be stored at 0 - 4 degrees C from the time of collection until analysis.

8.4 All samples must be analyzed within 28 days of the date and time collected.

9.0 Quality Control

9.1 For every set of ten samples, analyze a reagent blank, a known-value check sample, and a duplicate. Analysis of blanks is to show freedom from contamination.

9.2 Analyze a sample bottle blank with each set of samples. See section 8.2 for details.



10.0 Calibration and Standardization

10.1 Use the standard described in section 7.4 for finding TC. If only TOC is to be found, there is a stock solution of organic carbon. The same concentrations can be made up for the organic carbon.

10.2 Depending on whether TC-IC is to be found or TOC is to be found, will determine what curve or curves need to be set active. If just TOC is to be found, then choose SETUP, CALIBRATION, SET ACTIVE, then choose TOC. It will then give ranges of different values.

The choice that has been used is 20ppm-200ppm for most samples. If TOC is found by way of TC-IC, both curves for TC and IC must be set active. They also must have the same range of calibration. The TOC range should not be set active.

10.3 Once the calibration curve is formed, stop the run and go to the calibration results. Choose the standards that have just been run and click on the RECALC button. If you want to keep the curve click on OK and then start the run again. The curve is supposed to be linear, so the closer to 1.0000 the better the curve.

11.0 Procedure

11.1 Filtration of drinking water-related samples prior to TOC analysis is not permitted as this could result in removal of organic carbon. Where turbidity interferes with TOC analysis, samples should be homogenized and, if necessary, diluted with organic-free reagent water.

11.2 Bring the analytical batch of samples to room temperature. Make sure the samples are homogenized and pour into labeled amber 40 mL vials. Put on a new septa and place on the rack.

11.3 Check the carbonate and bicarbonate levels of the samples to be analyzed. If they are over 800 mg/L then dilute.

11.4 Make up the reagents weekly. Make up new standards when quality control checks start to fail.

11.5 Warm up the instrument at least one-half hour before use. This means just switch from standby to run, and make sure that the gas flow is 200 cc/min. Make sure the baseline has stabilized.

11.6 Create a file and label it according to the current date. An easy way to do this is to load an old file from the setup menu and change the samples that are in it to go along with the new run. Go to the file and use the "save as" and then type in the day of the run. Put the year first then the month and then day. Example: for the date of January 21st, 2002 should be read as 020121.

11.7 Set the curve for the desired analysis. The TOC curve should be set for analyzing drinking water-related samples. The TC and IC curve needs to be set active for analysis of TOC by difference. Make sure that all other curves that are not used are not active.

11.8 Put the samples on and select run.

11.9 The calibration curve should be checked after the first standard is run. This will be sure that the correct calibration is made. The analyst can choose the points on the calibration menu. The more linear the line the better, so if the r-squared number is close to one, and the check sample is in the tolerance limits, let the rest of the samples run.

11.10 Only TOC results will be displayed for the drinking water-related samples; whereas, the TOC by difference will be shown as TC, IC, and TOC on the results portion of the screen.

12.0 Data Analysis, Calculations, and Reporting Results

12.1 Calculations

If the instrument does not already do this, calculate corrected instrument response of standards and samples by subtracting the reagent-water blank instrument response vs. TOC concentration. Subtract procedural blank from each sample instrument response and compare to standard curve to determine carbon content. Apply appropriate dilution factor when necessary. Subtract inorganic carbon from total carbon when TOC is determined by difference.

12.2 Reporting Results

The results can be hand entered or electronically transferred to the Laboratory Information Management System (LIMS). The units should be mg/L.

13.0 Method Performance

Interlaboratory studies of persulfate and/or UV with NDIR detection methods have been conducted in the range of 0.1 mg/L to 4,000 mg/L of carbon. The resulting equation for organic carbon single-operator precision is :

$$S_o = 0.04 x + 0.1$$

Overall precision is expressed as: $S_t = 0.08x + 0.1$

where:

S_o = single-operator precision

S_t = overall precision, and

x = TOC concentration, mg/L

14.0 Pollution Prevention

If mercuric nitrate is used to complex the chloride, use an appropriate disposal method for the treated waste to prevent mercury contamination.

15.0 Waste Management

15.1 Disposal of any hazardous waste from this method must be done in accordance with appropriate regulations.

15.2 For further information on waste management consult The Waste Management Manual for Laboratory Personnel and Less is Better: Laboratory Chemical Management for Waste Reduction, both available from the American Chemical society's Department of Government Relations and Science Policy, 1155 16th Street N.W., Washington D.C. 20036

16.0 References

16.1 Method 5310 C: Total Organic Carbon (TOC), Persulfate-Ultraviolet or Heated-Persulfate Oxidation Method, *Standard Methods for the Examination of Water and Wastewater*, 19th edition supplement, 1996, pp.9-14.

16.2 "Dohrman Phoenix 8000 User Manual", 7413 East Kemper Road, Cincinnati, Ohio 45242-9576.

16.3 *Federal Register*, Wednesday, December 16, 1998, p 69417.



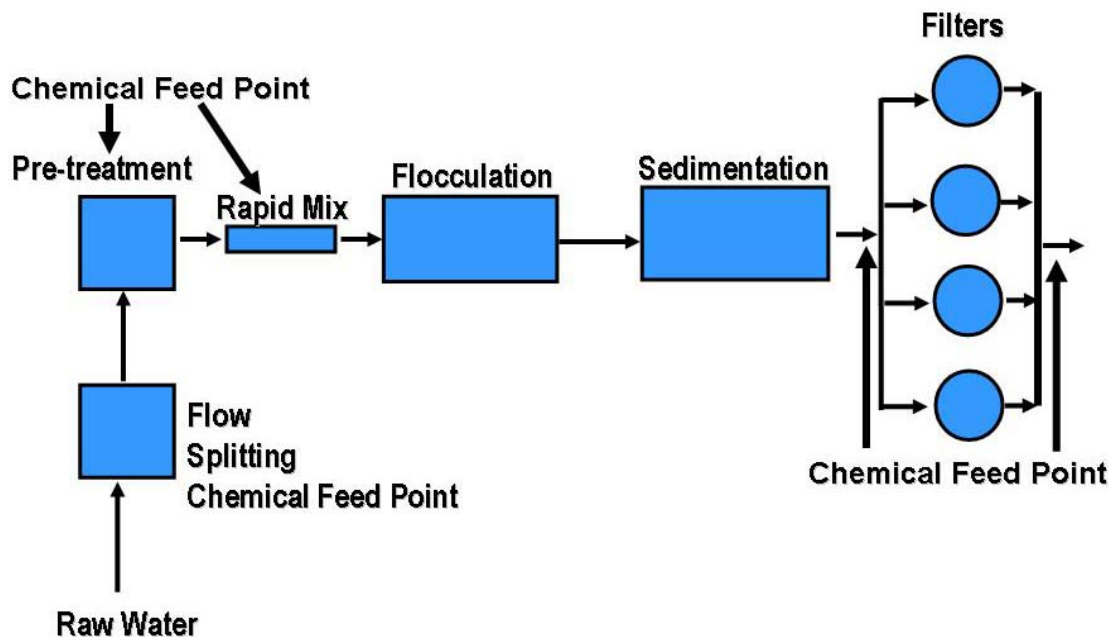
Samples to be extracted for analysis of TOC and other parameters.



The lab technician is holding a positive sample for Total Coliform.

Chemicals Used and the Feed Points

This section will look at the different locations of chemical feed points and how they affect the process and the possible implications they may have with EPA regulations. The diagram below shows a basic train used for most surface water treatment plants and where chemicals are typically added.



Adding **Copper Sulfate** at the splitter box shown above. Copper, which occurs naturally in water, also is used sometimes in water treatment in the form of copper sulfate to control algae. If overfed, copper sulfate could lower dissolved Oxygen levels. In addition, drinking water may interact with copper as the water travels through copper pipes or fixtures. The results of studies show that the presence of copper increases the formation of chloroform in water when chlorine is present. This suggests that copper may play a role in the formation of some THMs. Another consideration would be how copper sulfate would interfere with the Lead and Copper Rule.

Post chlorination is a practice of the past; however some surface water plants depending on the NOM will use it for color, taste and odor control. Most plants prefer the use **Powdered Activated Carbon**. This could be added at a splitter box as shown in the photograph on the right or during pre treatment as long as a plant can provide rapid mixing. Powder Activated Carbon has some potential in the lowering of TOC however overfeeding could potential cause problems with chlorine residuals.



Most treatment facilities use chemicals such as **Sulfuric acid** (H_2SO_4) and **Caustic soda** (sodium hydroxide, NaOH) to change pH. In addition, sulfuric acid is used in the enhanced coagulation process to buffer alkalinity in order to lower levels of TOC. Depending on plant design, sulfuric acid is added to pre-treatment or pre-sedimentation and it could be added at the rapid mix. When pH is lowered below 7, then caustic is used to raise the pH--this is fed at the effluent. Care must be taken when feeding chlorine; the pH should not be above 8. If alkalinity is low due to acid rain or source water, caustic soda is fed at the pre-sedimentation process.

Polymers are used as coagulants and filter aids. Some plants use a cationic polymer for coagulation that is delivered in bulk storage and the concentration of the polymer may vary. The polymer used as a coagulant aid is possibly fed at pre-sedimentation and the flash mixer. This chemical is used to enhance particle removal. Filter aid polymer also varies depending on the manufacturer and how the chemical is prepared. Filter aid is used to enhance additional removal of particles prior to the filter. When using Polymers, Jar Testing is highly recommended.



The photograph on the left is bulk storage and on the right a day mixing tank of polymer.

Aluminum sulfate (Alum) is the most common coagulant used at a conventional water treatment plant; however, some plants use Iron salts instead. Most EPA guidelines for enhanced coagulation focus on Alum due to its success in lowering TOC, plus it is cost efficient. Plants can feed coagulants at the pre-sedimentation basins, as well as prior to flocculation. The optimum pH level for Alum is between 5.5 – 7.0. In order to find the best feed rates, the process control specialist will perform a Jar test to see how much TOC can be decreased.

After filtration, Chlorination is used to prevent waterborne diseases. **Chlorine** is the major disinfectant chemical used today, even though the potential of cancer-causing by-products are present, it does the best job in deactivating pathogens. Most plants feed chlorine in the combined effluent channel downstream from caustic soda. Contact time is the key to achieve Log removal.

More on Water Treatment Chemicals

Similar chemicals are used for process control, odor control and sludge conditioning in Water and Wastewater Treatment. Students will learn about the types of chemicals used and how they react in the process. Students will also learn about chemical safety and perform on-site equipment assessment.

The table below is a list of **general** chemicals used in Water and Wastewater. They may vary by the manufacture; a perfect example would be Thioguard®, which is Magnesium Hydroxide. In this class we will discuss the chemical name and compound and leave out manufacture trade names.

Common Water/Wastewater Treatment Chemicals

Chemical Name	Common Name	Chemical Formula	pH (Raise or Lowers)
Aluminum hydroxide		$\text{Al}(\text{OH})_3$	
Aluminum sulfate	Alum, liquid	$\text{Al}_2(\text{SO}_4)_3 \cdot 14(\text{H}_2\text{O})$	
Ammonia		NH_3	
Ammonium		NH_4	
Bentonitic clay	Bentonite		
Calcium bicarbonate		$\text{Ca}(\text{HCO}_3)_2$	
Calcium carbonate	Limestone	CaCO_3	
Calcium chloride		CaCl_2	
Calcium Hypochlorite	HTH	$\text{Ca}(\text{OCl})_2 \cdot 4\text{H}_2\text{O}$	
Calcium hydroxide	Slaked Lime	$\text{Ca}(\text{OH})_2$	
Calcium oxide	Unslaked (Quicklime)	CaO	
Calcium sulfate	Gypsum	CaSO_4	
Carbon	Activated Carbon	C	
Carbon dioxide		CO_2	
Carbonic acid		H_2CO_3	
Chlorine gas		Cl_2	
Chlorine Dioxide		ClO_2	
Copper sulfate	Blue vitriol	$\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$	
Dichloramine		NHCl_2	
Ferric chloride	Iron chloride	FeCl_3	
Ferric hydroxide		$\text{Fe}(\text{OH})_3$	
Ferric sulfate	Iron sulfate	$\text{Fe}_2(\text{SO}_4)_3$	
Ferrous bicarbonate		$\text{Fe}(\text{HCO}_3)_2$	
Ferrous hydroxide		$\text{Fe}(\text{OH})_3$	
Ferrous sulfate	Copperas	$\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$	
Hydrofluorsilicic acid		H_2SiF_6	
Hydrochloric acid	Muriatic acid	HCl	

Chemical Name	Common Name	Chemical Formula	pH (Raise or Lowers)
Hypochlorous acid		HOCL	
Magnesium bicarbonate		Mg(HCO ₃) ₂	
Magnesium carbonate		MgCO ₃	
Magnesium chloride		MgCl ₂	
Magnesium hydroxide		Mg(OH) ₂	
Magnesium dioxide		MgO ₂	
Manganous bicarbonate		Mn(HCO ₃) ₂	
Manganous sulfate		MnSO ₄	
Monochloramine		NH ₂ Cl	
Potassium bicarbonate		KHCO ₃	
Potassium permanganate		KMnO ₄	
Sodium carbonate	Soda ash	Na ₂ CO ₃	
Sodium chloride	Salt	NaCl	
Sodium chlorite		NaClO ₂	
Sodium fluoride		NaF	
Sodium fluorsilicate		Na ₂ SiF ₆	
Sodium hydroxide	Lye	NaOH	
Sodium hypochlorite		NaOCl	
Sodium Metaphosphate	Hexametaphosphate	NaPO ₃	
Sodium phosphate	Disodium phosphate	Na ₃ PO ₄	
Sodium sulfate		Na ₂ SO ₄	
Sulfuric acid		H ₂ SO ₄	



Solubility of Substances in Water

Water is an excellent solvent for many compounds. Some dissolve in it as molecules while others, called electrolytes, dissociate and dissolve not as neutral molecules but as charged species called ions. Compounds which exist as solid ionic crystals dissolve in water as ions, and most of them are highly soluble in water. "Highly soluble" is a somewhat elastic description, but generally means soluble to at least the extent of forming 0.1 to 1.0 molar aqueous solutions. Salts which are less soluble in water than this at room temperature are called slightly soluble salts.

The solubility of an ionic salt depends both upon its cations and its anions, but for simple salts in aqueous solution at room temperature the following general observations are useful. Almost all sodium, potassium, and ammonium salts are highly soluble; the only significant exception is KClO_4 , which is moderately soluble almost without exception. Metal carbonates and phosphates are generally insoluble or slightly soluble, with the exception of those of sodium, potassium, and ammonium which are highly soluble; magnesium ammonium phosphate is used for the precipitation of magnesium ion.

Metal halides are generally highly soluble, with the exception of those of silver, lead, and mercury (I). Lead chloride is slightly soluble while silver and mercury (I) chlorides are much less soluble. Sulfate salts are generally highly soluble as well, with more exceptions; calcium, barium, strontium, lead, and mercury (I) sulfates are almost insoluble while silver sulfate is slightly soluble. Metal sulfides are generally insoluble in water.

Solid-Solution (Solubility) Reactions

When solids dissolve, the solutes are no longer pure substances and their activity can no longer be taken as unity. In dilute solutions, aqueous or otherwise, activities of solutes are often taken as equal to their molar concentrations. These equilibria are called solubility equilibria and are taken up under the following main heading. The example below shows how the form in which they are written compares to other equilibrium constants.

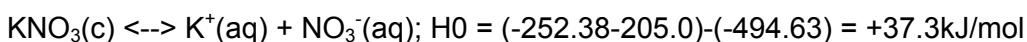
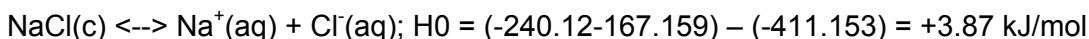
Example. The equilibrium constant for the reaction $\text{AgCl(s)} \rightleftharpoons \text{Ag}^+(\text{aq}) + \text{Cl}^-(\text{aq})$ is written as $K = a(\text{Ag}^+)a(\text{Cl}^-)/a(\text{AgCl})$; more commonly, it is written in the form $K_a(\text{AgCl}) = a(\text{Ag}^+)a(\text{Cl}^-) = K_{\text{sp}}$. If the molar concentrations are taken as good approximations to the activities, which in dilute solutions they are, then $K_{\text{sp}} = [\text{Ag}^+][\text{Cl}^-]$.

Example. Let us write and simplify to the extent possible the equilibrium constant for the equilibrium $\text{Al}^{3+}(\text{aq}) + 3\text{OH}^-(\text{aq}) \rightleftharpoons \text{Al}(\text{OH})_3(\text{s})$. For this equilibrium $K = 1/[\text{Al}^{3+}][\text{OH}^-]^3 = 1/K_{\text{sp}}$, where K has the units $\text{dm}^{12}/\text{mol}^4$, or $(\text{dm}^3)^4/\text{mol}^4$.

The form of equilibrium constant indicated as K_{sp} is called the solubility product constant or, more commonly, the solubility product. This constant therefore must refer to the process of a solid going into solution (solubility) rather than the reverse, precipitation of solid from solution. As a consequence, the ions are products and appear in the numerator. The value of the solubility product is temperature-dependent and is generally found to increase with increasing temperature. As a consequence, the molar solubility of ionic salts generally increases with increasing temperature. The extent of this increase varies from one salt to another.

It is sometimes possible to take advantage of the difference in the effect of temperature to separate mixtures of different soluble salts. As the chart in the following Figure shows, a solution originally of equal concentration in KClO_3 and KNO_3 should upon heating and evaporation of water precipitate KClO_3 because KNO_3 is by far the more soluble near the boiling point of water.

The solubility of solid salts in water, and in most other solvents, increases with temperature while that of gases decreases. The heat or enthalpy change of the dissolution reaction for most solids is positive so the dissolution reaction is endothermic. For some solids, such as NaCl , the heat of solution is very small and so the effect of temperature is small also. For other salts, such as KNO_3 , the effect of temperature is much larger:



Chemical coagulation in the water/wastewater treatment is the process of bringing suspended matter in untreated water together for the purpose of settling and for the preparation of the water for filtration.

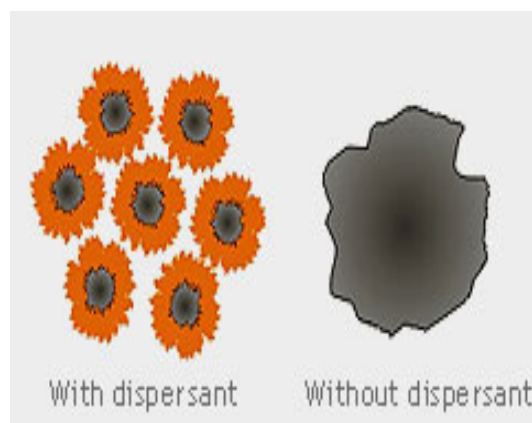
Coagulation involves three specific steps, which are:

- ◆ Coagulation
- ◆ Flocculation
- ◆ Sedimentation

Purpose of Coagulation

Untreated surface waters contain clay, minerals, bacteria, inert solids, microbiological organisms, oxidized metals, organic color producing particles, and other suspended materials. Some of the microbiological organisms can include Giardia cysts, pathogenic bacteria, and viruses. Oxidized metals include iron and manganese. All of these materials can inhibit disinfection, cause problems in the distribution system, and leave the water cloudy rather than clear. The purpose of coagulation is to remove these particles.

The ability of particles to remain suspended in water is a function of both the particle size and specific gravity. Turbidity particles can range in size from molecular to 50 microns. Particles which are greater than one micron in diameter are considered silt, and settle out due to their relatively large size and density without the need to coagulate in a matter of seconds or minutes.



Colloidal material ranges in size from 0.001 to one micron in diameter. These materials require days to months for complete settling. Since detention times in the water treatment process are generally less than twelve hours, the rate of settling of these colloidal particles must be increased in the water treatment process.

This is accomplished in the coagulation process when tiny particles agglomerate into larger, denser particles which will settle more quickly as shown in the picture on the right.

These tiny colloidal particles have a very large surface area to mass ratio, and this factor is important in keeping the particles suspended for long periods of time. In fact, the surface area to mass ratio is so high that electric charges and ionic groups become important in keeping the particles suspended. Two types of colloids exist. These are hydrophobic or water hating colloids, and hydrophilic or water loving colloids. Hydrophilic colloids form suspensions easily, and can be difficult to remove. These colloids can, however, react chemically with the coagulants commonly added to water under proper conditions. Examples of hydrophilic colloids would be organic color forming compounds. Hydrophobic colloids do not easily form suspensions. The reactions between hydrophobic colloids and the coagulants commonly added to water are largely physical rather than chemical. Examples of hydrophobic colloids would be clays and metal oxides.

The Coagulation Process

Coagulation is accomplished by the addition of ions having the opposite charge to that of the colloidal particles. Since the colloidal particles are almost always negatively charged, the ions which are added should be cations or positively charged. The coagulating power of an ion is dependent on its valency or magnitude of charge. A bivalent ion (+2 charge) is 30 to 60 times more effective than a monovalent ion (+1 charge). A trivalent ion (+3 charge) is 700 to 1000 times more effective than a monovalent ion.

Typically, two major types of coagulants are added to water. These are aluminum salts and iron salts. The most common aluminum salt is aluminum sulfate, or alum. When aluminum sulfate is added to water, the aluminum ions enter into a series of complicated reactions. The aluminum ions become hydrated, meaning that water molecules attach themselves to the aluminum ions. In addition, anions present in the water, such as hydroxide and sulfate ions can attach to the aluminum ions. These reactions result in large, positively charged molecules having aluminum ions at their center. These particles may have charges as high as +4. Following these reactions, a second type of reaction occurs, called Olation. This reaction involves the bridging of two or more of these large molecules to form even larger, positively charged ions. A typical molecule can contain eight aluminum ions, twenty hydroxide ions, and will have a +4 charge. Iron salts behave in a similar manner when added to water.

Once these large polymeric aluminum or iron compounds are formed, the magnitude of their high positive charge allows these species to rapidly move toward the colloid, where they are adsorbed onto the negatively charged surface of the turbidity particle. The coagulant compounds can penetrate the bound water layer because of their high positive charge. This rapid adsorption results in the compression of the electrical double layer, and results in the colloid becoming coated with the coagulant compounds. The net result of this process is that the electrical charges on the particle are reduced. The suspension is now considered to be destabilized, and the particles can be brought together through, among other forces, Brownian Movement, and will be held together by the Van der Waals forces.

An additional process occurs which assists this process. As the coagulant continues to undergo the hydrolyzation and olation reactions, progressively larger masses of flocculent material are formed. These compounds can become large enough to settle on their own, and tend to trap turbidity particles as they settle. This is commonly referred to as sweep floc.

As the coagulation reactions and destabilization are occurring, the Zeta Potential at the surface of the colloid is also found to be reducing. Typically, the Zeta Potential for a naturally occurring water may be in the range of -10 to -25 millivolts. As the reactions occur, this Zeta Potential will be reduced to approximately -5 millivolts. These figures are only examples of what might be considered typical waters. Since all waters exhibit a specific set of characteristics, these numbers will vary. It is interesting to note that the Zeta Potential does not have to be reduced to zero in order for coagulation to occur, because the forces of attraction can become predominant before complete destabilization occurs.

Hydrophilic colloids participate in the coagulation process in a slightly different way. These colloids tend to attract water molecules and attach these water molecules to their surfaces. This is also a hydration process, and the water molecules act as a barrier to contact between particles. Also attached to the surfaces are hydroxyl, carboxyl, and phosphate groups, all to which are negatively charged. Coagulant products react chemically with the negatively charged groups attached to the hydrophilic colloids, forming an insoluble product which is electrically neutral and destabilized.

Factors Influencing Coagulation

Effects of pH: The pH range in which a coagulation process occurs may be the single most important factor in proper coagulation. The vast majority of coagulation problems are related to improper pH levels. Whenever possible, coagulation should be conducted in the optimum pH zone. When this is not done, lower coagulation efficiency results, generally resulting in a waste of chemicals and a lowered water quality. Each of the inorganic salt coagulants has its own characteristic optimum pH range. In many plants, it is necessary to adjust the pH level in the coagulation process. In most cases this involves the addition of lime, caustic soda, or soda ash to maintain a minimum pH level. In some cases, however, acids may be necessary to lower the pH level to an optimum range. In some water plants, the acidic reactions of the inorganic salts are taken advantage of when the raw water pH levels are higher than desired. In these instances, overfeed of the coagulant is intentionally induced in order for the coagulation process to occur in the optimum range.

Effects of salts: Since no natural waters are completely pure, each will have various levels of cations and anions such as calcium, sodium, magnesium, iron, manganese, sulfate, chloride, phosphate, and others. Some of these ions may affect the efficiency of the coagulation process. Generally, mono and divalent cations such as sodium, calcium, and magnesium have little or no effect on the coagulation process. Trivalent cations do not have an adverse effect on the process in most instances. In fact, significant concentrations of naturally occurring iron in a water supply has resulted in the ability to feed lower than normal dosages of inorganic salt coagulants.

Some anions can have a more pronounced effect. Generally, monovalent anions such as chloride have little effect on the coagulation process. As the concentration of the divalent anion sulfate in a water supply increases, the optimum pH range of the inorganic salt coagulants tends to broaden, generally toward the lower pH levels. As the concentration of phosphate ions increase, the optimum range of pH tends to shift to lower pH levels, without broadening. These effects could cause a disruption of the coagulation process if abrupt changes in the concentrations of these anions occur in the water supply.

Nature of turbidity: The turbidity in natural surface waters is composed of a large number of sizes of particles. The sizes of particles can be changing constantly, depending on precipitation and manmade factors. When heavy rains occur, runoff into streams, rivers, and reservoirs occurs, causing turbidity levels to increase. In most cases, the particle sizes are relatively large and settle relatively quickly in both the water treatment plant and the source of supply. However, in some instances, fine, colloidal material may be present in the supply, which may cause some difficulty in the coagulation process. Generally, higher turbidity levels require higher coagulant dosages. However, seldom is the relationship between turbidity level and coagulant dosage linear. Usually, the additional coagulant required is relatively small when turbidities are much higher than normal due to higher collision probabilities of the colloids during high turbidities. Conversely, low turbidity waters can be very difficult to coagulate due to the difficulty in inducing collision between the colloids. In this instance, floc formation is poor, and much of the turbidity is carried directly to the filters. Organic colloids may be present in a water supply due to pollution, and these colloids can be difficult to remove in the coagulation process. In this situation, higher coagulant dosages are generally required.

Water temperature: Cold water temperatures can cause two factors which add to the difficulty of the coagulation process. As water temperatures approach freezing, almost all chemical reactions occur more slowly. It can be more difficult therefore to evenly disperse the coagulants into the water. As a result, the coagulant process becomes less efficient, and higher coagulant dosages are generally used to compensate for these effects. In addition, floc settling characteristics become poor due to the higher density of the water during near freezing temperatures.

Mixing Effects: Poor or inadequate mixing results in an uneven dispersion of the coagulant. Unfortunately, many older plants were designed with mixing facilities which generally do not accomplish mixing in the most efficient manner. As a result, it becomes necessary to use higher than necessary dosages of coagulant to achieve an optimum level of efficiency in the process. The effects of low turbidity and cold water temperatures can tend to aggravate the lack of adequate mixing facilities in some plants.

Effect of the coagulant: The choice of the proper coagulant for the given conditions is of critical importance in maintaining an efficient coagulation scheme under widely varying conditions. The chemicals most commonly used in the coagulation process are Aluminum Sulfate, Ferric Chloride, Ferric Sulfate, and Cationic Polymers.

Coagulants

Aluminum Sulfate (Alum): Aluminum Sulfate is also known as alum, filter alum, and alumina sulfate. Alum is the most widely used coagulant. Alum is available in dry form as a powder or in lump form. It can also be purchased and fed as a liquid. Alum has no exact formula due to the varying water molecules of hydration which may be attached to the aluminum sulfate molecule...Once in water, alum can react with hydroxides, carbonates, bicarbonates, and other anions as discussed previously to form large, positively charged molecules...Carbon dioxide and sulfate are generally byproducts of these reactions. During the reactions, alum acts as an acid to reduce the pH and alkalinity of the water supply. It is important that sufficient alkalinity be present in the water supply for the various reactions to occur.

On a theoretical basis, 1.0 mg/l of dry alum will react with:

0.50 mg/l of natural alkalinity as calcium carbonate

0.33 mg/l of 85% quicklime as calcium oxide

0.39 mg/l of 95% hydrated lime as calcium hydroxide

0.54 mg/l of soda ash as sodium carbonate

Alum can be effective in the pH range of 5.5 to 7.8, but seems to work best in most water supplies in a pH range of 6.8 to 7.5. Below a pH range of 5.5, alkalinity in the water supply is generally insufficient. The aluminum ions become soluble rather than insoluble and do not participate in the hydration and olation reactions necessary to make the alum effective as a coagulant. In these instances the plant may experience higher than normal filtered water turbidities, and much of the aluminum will pass through the filters.

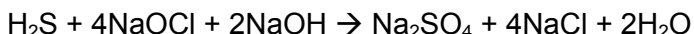
When the pH level of the water is above 7.8 after the addition of the alum, the aluminum ions again become soluble, and the efficiency of coagulation is decreased. Under these conditions, aluminum ions again penetrate the filters, and post filtration alum coagulation can occur in the clear well and in the distribution system in some cases.

Ferric Chloride (Ferric): Traditionally, ferric chloride has not been used widely as a coagulant, but this trend is not continuing. Ferric chloride is becoming more extensively used as a coagulant due partially to the fact that the material can be purchased as a liquid.

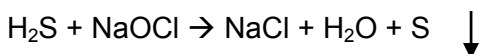
Ferric chloride may also be purchased as an anhydrous solid. Liquid ferric chloride is highly corrosive, and must be isolated from all corrodible metals. Like ferric sulfate, ferric chloride exhibits a wide pH range for coagulation, and the ferric ion does not easily become soluble. As a result, many plants are replacing alum with ferric chloride to eliminate the penetration of aluminum ions through the plant filters. Ferric chloride also reacts as an acid in water to reduce alkalinity. Other inorganic coagulants are available, such as potash alum, ammonia alum, ferrous sulfate (copperas), and chlorinated copperas. None of these materials are widely used. Typical dosages of the inorganic coagulants range from 50 pounds per million gallons of water treated under ideal conditions to as high as 800 to 1000 pounds per million gallons of water treated under worst case conditions.

H₂S Control – Traditional Wet Scrubbing using Chemicals

The most common method of control of H₂S gas is to pass the smelly gas through a vertical, packed bed wet scrubber. The air passes up the tower as the scrubbing liquid containing caustic (NaOH) and oxidizing agent (most often bleach or NaOCl, sodium hypochlorite) flows down the tower in the counter-current fashion. The high pH provided by the caustic drives the mass transfer from gas to liquid phase by solubilizing H₂S as HS⁻ bisulfide and S⁻² sulfide ions. Once in solution, the reaction between hydrogen sulfide and oxidizing agent is almost instantaneous (assuming sufficient oxidizing agent is present). This reaction converts the sulfide to sulfate (SO₄⁻²) ion. The overall chemical reaction is described by the following equation:



Therefore, theoretically, for each molecule of H₂S destroyed, four molecules of bleach and two molecules of caustic are consumed. However, the chemistry is not quite so simple, as partial oxidation of H₂S also takes place which forms elemental sulfur:



This reaction represents about 1% of the chemistry present in a wet scrubber. The presence of excess bleach helps to minimize the formation of elemental sulfur. But bleach is an expensive chemical. The use of two stage scrubbing is often employed both to minimize chemical consumption as well as to control sulfur deposits when scrubbing H₂S. The first stage operates at 80% efficiency and uses a caustic only scrub at high pH (12.5). The air then passes to the second stage, where the remaining H₂S is scrubbed with caustic / bleach solution at pH 9.5. The H₂S present is destroyed at 99%+ efficiency. The blowdown from the 2nd stage, which will contain some amount of unused NaOCl, is sent to the sump of the 1st stage. In this way additional H₂S is destroyed and maximum consumption of expensive oxidizing agent is assured.

Never the less, there are losses of chemicals which cannot be prevented, which of course raise the cost of odor scrubbing. These losses are due to the facts that bleach, NaOCl, slowly decomposes in storage as well as the fact that some amount of caustic is constantly lost to CO₂ absorption in both scrubbing stages.

Emissions

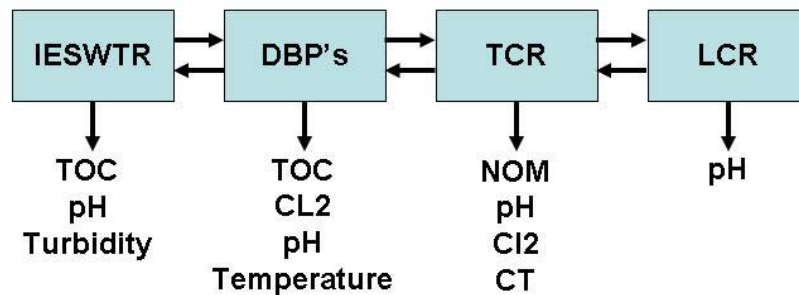
Volatile organic compounds (VOCs) are the primary air pollutants emitted from rendering operations. The major constituents that have been qualitatively identified as potential emissions include organic sulfides, disulfides, C-4 to C-7 aldehydes, trimethylamine, C-4 amines, quinoline, dimethyl pyrazine, other pyrazines, and C-3 to C-6 organic acids. In addition, lesser amounts of C-4 to C-7 alcohols, ketones, aliphatic hydrocarbons, and aromatic compounds are potentially emitted. No quantitative emission data were presented.

Historically, the VOCs are considered an odor nuisance in residential areas in close proximity to rendering plants, and emission controls are directed toward odor elimination. The odor detection threshold for many of these compounds is low; some as low as 1 part per billion (ppb). Of the specific constituents listed, only quinoline is classified as a hazardous air pollutant (HAP). In addition to emissions from rendering operations, VOCs may be emitted from the boilers used to generate steam for the operation.

The Balance between Process Control and EPA Requirements

The challenge facing any person involved with process control is the delicate balance between Microbial Contamination and DBP's. The picture below shows the parameters that change and how they correlate with the rule.

Rules that Challenge Surface Water Treatment



Parameters that Affect Them

So far we have looked at several types of chemicals and their potential feed points. The equipment associated with them is another crucial component of the process and should be highly considered. Depending on the chemical substance, feed equipment will vary. In addition, plants may use different manufacturers which creates challenges when it comes to operating and maintaining equipment. Because of the complexity of the equipment, future course training will address this function.



Backwashing a filter.



Some plants use Lime as a coagulant or for softening. This is a lime slacker.

Glossary

ABANDONED WELL: Wells that have been or need to be sealed by an approved method.

ABSENCE OF OXYGEN: The complete absence of oxygen in water described as Anaerobic.

ACCURACY: How closely an instrument measures the true or actual value.

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: Slowly add the acid to water while stirring. An operator should not mix acid and water or acid to a strong base.

ACID RAIN: A result of airborne pollutants.

ACTIVATED CHARCOAL (GAC or PAC): Granular Activated Charcoal or Powered Activated Charcoal. Used for taste and odor removal. A treatment technique that is not included in the grading of a water facility.

ACTIVATED CARBON FILTRATION: Can remove organic chemicals that produce off-taste and odor. These compounds are not dangerous to health but can make the water unpleasant to drink. Carbon filtration comes in several forms, from small filters that attach to sink faucets to large tanks that contain removable cartridges. Activated carbon filters require regular maintenance or they can become a health hazard.

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 CLARIFIERS: The concept of the adsorption clarifier package plant was developed in the early 1980s. This technology uses an up-flow clarifier with low-density plastic bead media, usually held in place by a screen. This adsorption media is designed to enhance the sedimentation/clarification process by combining flocculation and sedimentation into one step. In this step, turbidity is reduced by adsorption of the coagulated and flocculated solids onto the adsorption media and onto the solids already adsorbed onto the media. Air scouring cleans adsorption clarifiers followed by water flushing. Cleaning of this type of clarifier is initiated more often than filter backwashing because the clarifier removes more solids. As with the tube-settler type of package plant, the sedimentation/ clarification process is followed by mixed-media filtration and disinfection to complete the water treatment.

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 HAMMER: A pneumatic cylindrical hammering device containing a piston used on air rotary rigs. The air hammer's heavy piston moves up and down by the introduction of compressed air creating a hammering action on the bit.

AIR HOOD: The most suitable protection when working with a chemical that produces dangerous fumes.

AIR ENTRAINMENT: The dissolution or inclusion of air bubbles into water.

AIRLIFT: The lifting of water and/or cuttings to the surface by the injection of high pressure bursts of air. Airlift occurs continuously when drilling with air rotary and can be used for well development with a surging technique.

AIR PUMPING: Continuous airlifting to remove water from the well.

AIR ROTARY: A method of rotary well drilling that utilizes compressed air as the primary drilling fluid.

AGGLOMERATION: A jumbled cluster or mass of varied parts. The act or process of agglomerating.

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).

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.

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.

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.

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.

AMMONIA: NH_3 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.

AMMONIATOR: A control device which meters gaseous ammonia directly into water under positive pressure.

ANAEROBIC: 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.

ANEROID: Using no fluid, as in aneroid barometer.

ASEPTIC: Free from the living germs of disease, fermentation, or putrefaction.

ANNULAR SPACE: The space between the borehole wall and either drill piping or casing within a well.

ANNULUS: See Annular Space.

AMMONIA: A chemical made with Nitrogen and Hydrogen and used with chlorine to disinfect water.

AQUICLUDE: A layer or layers of soils or formations which water cannot pass through (ex - solid bedrock or very stiff clay). The opposite of aquifer.

AQUIFER: A saturated layer or layers of soils or formations which water can pass through and be provided in usable quantities to supply wells or springs (ex – saturated semi consolidated sediment or saturated fractured bedrock.) An underground geologic formation capable of storing significant amounts of water.

AQUIFER PARAMETERS: Referring to such attributes as specific capacity, aquifer storage, transmissivity, hydraulic conductivity, gradient, and water levels. Refers to all of the components of Darcy's Law and related parameters.

ARTESIAN AQUIFER: A confined aquifer in which the pressure head results in a water elevation higher than the land surface.

ARTESIAN WELL: A well constructed within an artesian aquifer. When an artesian well is opened it will flow naturally.

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.

ASYNCHRONOUS: Not occurring at the same time.

AUGER RIG: A drilling rig, which drives a rotating spiral flange to drill into the earth.

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.

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.

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.

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: Any of a group of viruses that infect specific bacteria, usually causing their disintegration or dissolution. 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.

BAILER: A device used to withdrawal water or sediment from a well utilizing a check valve type mechanism.

BARITE: Processed barium sulfate, often used to increase drilling fluid densities in mud rotary.

BATTERY: 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.

BENTONITE: High quality clay composed primarily of montmorillonite. Used to thicken drilling mud in mud rotary drilling and used to form seals in well construction or abandonment.

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.

BIT: The primary cutting edge of a drill string.

BLANK CASING: A section of well casing that is solid.

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.

BOREHOLE DEVIATION: A boreholes' orientation deviates from vertical while drilling.

BOREHOLE GEOPHYSICS: A surveying technique of utilizing specialized tools to measure various physical parameters of the aquifer, formation, and well.

BOREHOLE: The hole that is formed when drilling into the earth.

BOULDER: An individual rock or solid mass of rock larger than 10 inches in diameter.

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.

BRIDGING: The tendency of sediment, filter, or seal media to create an obstruction if installed in too small an annulus or too rapidly. Also can occur within filter packs requiring development.

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.

BUCKET AUGER: A single cylindrical type of auger flight consisting of offset cutting blades at the bottom. A bucket auger rig rotates the bucket and its blades cut into the earth and fill the bucket with cuttings, which are dumped on the surface as needed.

BUFFER: Chemical that resists pH change, e.g. sodium bicarbonate

BUTTON BIT: A bit that is constructed with raised (typically carbide) buttons that strengthen the bit and aid in crushing and grinding efficiency. A button bit may be of a roller, hammer, or percussion type.

CABLE TOOL: (Also called Percussion Drilling) A method of drilling which utilizes the consecutive lifting and dropping of a heavy drill string via a system of cables.

CALCIUM HARDNESS: A measure of the calcium salts dissolved in water.

Ca: The chemical symbol for calcium.

CADMIUM: A contaminant that is usually not found naturally in water or in very small amounts.

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.

CAPILLARY ACTION: The occurrence of an upward movement of fluid into previously unsaturated soil due to adhesion and surface tension which develops between the fluid and soil particles.

CAPILLARY FRINGE: The uppermost portion of an aquifer where the vadose zone ends. The capillary action of soils permits moisture to extend upwards into the vadose zone within the capillary fringe.

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 (CO_3^{2-}) and bicarbonate (HCO_3^-) 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 CaCO_3 " – 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 NaHCO_3 (baking soda), it would have a carbonate hardness of about 18 mg/L as CaCO_3 . If you had a liter of water containing 50 mg of Na_2CO_3 , it would have a carbonate hardness of about 29 mg/L as CaCO_3 .

CARBONATE, BICARBONATE AND HYDROXIDE: Chemicals that are responsible for the alkalinity of water.

CARBONATE ROCK: Rock that is composed primarily of calcium carbonate.

CASING DRIVER: A percussion or hammering device used to force casing into the subsurface.

CASING: A column of specially designed pipe of metal or plastic material installed in wells in order to keep a borehole open to permit serviceability of and/or construction and completion of a well within it.

CATHEAD: A specially designed auxiliary reel that normally utilizes heavy rope rather than steel cable. Often used on cable tool or percussion drilling rigs for the operation of drive blocks.

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.

CAVERN: Large open spaces (>5ft.) encountered while drilling. More often associated with limestone formations in a karst environment.

CEILING AREA: The specific gravity of ammonia gas is 0.60. If released, this gas will accumulate first at the ceiling area. Cl_2 gas will settle on the floor.

CEMENT GROUT: Cement of fine consistency, capable of being pumped. Used to seal in and around wells.

CENTRALIZER: Stand offs attached to well casing and screen to maintain annular space. In drilling, it has the same meaning as stabilizer or drill collar.

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.

CESIUM (also Caesium): Symbol Cs- A soft, silvery-white ductile metal, liquid at room temperature, the most electropositive and alkaline of the elements, used in photoelectric cells and to catalyze hydrogenation of some organic compounds.

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.

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 or Potassium Permanganate 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.

CHEMISORPTION: (or chemical adsorption) Is adsorption in which the forces involved are valence forces of the same kind as those operating in the formation of chemical compounds.

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.

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.

CLEAR WELL: A large underground storage facility sometimes made of concrete. A clear well or a plant storage reservoir is usually filled when demand is low. The final step in the conventional filtration process, the clearwell provides temporary storage for the treated water. The two main purposes for this storage are to have filtered water available for backwashing the filter and to provide detention time (or contact time) for the chlorine (or other disinfectant) to kill any microorganisms that may remain in the water.

CIO₂: The molecular formula of Chlorine dioxide.

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.

COBBLES: A rock smaller than a boulder but larger than a pebble. A cobble is greater than 2.5 inches in diameter and smaller than 10 inches in diameter.

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.

COMMUTATOR: A device for reversing the direction of a current. (in a DC motor or generator) a cylindrical ring or disk assembly of conducting members, individually insulated in a supporting structure with an exposed surface for contact with current-collecting brushes and mounted on the armature shaft, for changing the frequency or direction of the current in the armature windings.

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.

COMMUNITY WATER SYSTEM: A water system which supplies drinking water to 25 or more of the same people year-round in their residences.

COMPLIANCE CYCLE: A 9-calendar year time-frame during which a public water system is required to monitor. Each compliance cycle consists of 3 compliance periods.

COMPLAINE PERIOD: A 3-calendar year time-frame within a compliance cycle.

COMPLETION (WELL COMPLETION): Refers to the final construction of the well including the installation of pumping equipment.

COMPOSITE SAMPLE: A water sample that is a combination of a group of samples collected at various intervals during the day.

CONDENSATION: The process that changes water vapor to tiny droplets or ice crystals.

CONE OF DEPRESSION: That portion of the water table or potentiometric surface that experiences drawdown from a pumped well.

CONFINED AQUIFER: An aquifer that is isolated by confining layers on both its top and bottom. Pressures within a confined aquifer are normally greater than atmospheric pressure resulting in a potentiometric head.

CONFINING LAYER: An extensive layer of soil or formation that resists the movement of water from an aquifer below or above it. Confining layers isolate aquifers thereby confining them. May or may not be an aquiclude. (ex – Clay or silt rich layer)

CONSOLIDATED: Soil, sediment, or formation that is solidified or cemented together as a unit.

CONTACT TIME, pH and LOW TURBIDITY: Factors which are important in providing good disinfection using chlorine.

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: tr.v. con·tam·i·nated, con·tam·i·nat·ing, con·tam·i·nates
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.

CONTINUOUS SLOT SCREEN: A wire wrapped or plastic slotted screen in which the slot openings completely encircle the inner ribs of the screen.

CONTROL TASTE AND ODOR PROBLEMS: KMnO_4 Potassium permanganate is a strong oxidizer commonly used to control taste and odor problems.

CONVENTIONAL: A standard or common procedure to a group of more complex methods. (ex – Direct Rotary *conventional* vs. Reverse *non-conventional*)

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.

COUPON: A coupon placed to measure corrosion damage in the water mains.

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.

CUTTING HEAD (CUTTER HEAD): The bit portion of auger flighting that serves as the primary cutting edge of the auger.

CUTTING SHOE: A hardened steel sleeve with a wedged or armored cutting edge that is installed on well casing that is to be driven into the earth.

CUTTINGS: Crushed rock, soil, or formation material generated by the drilling action of a bit.

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: White, crystalline, water-soluble solid, $\text{C}_3\text{H}_3\text{O}_3\text{N}_3 \cdot 2\text{H}_2\text{O}$, used chiefly in organic synthesis. 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.

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 or fume hood.

DARCY'S LAW: ($Q=KIA$) A fundamental equation used in the groundwater sciences to determine aquifer characteristics, where Q =Flux, K =Hydraulic Conductivity (Permeability), I = Hydraulic Gradient (change in head), and A = Cross Sectional Area of flow.

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.

DENTAL CRIES PREVENTION IN CHILDREN: The main reason that fluoride is added to a water supply.

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.

DEVELOPMENT: The cleaning of the well and bore once construction is complete.

DETENTION LAG: Is the period of time between the moment of change in a chlorinator control system and the moment when the change is sensed by the chlorine residual indicator.

DETENTION LAG TIME: The minimum detention time range recommended for flocculation is 5 – 20 minutes for direct filtration and up to 30 minutes for conventional filtration.

DIATOMACEOUS EARTH: A fine silica material containing the skeletal remains of algae.

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.

DIRECT ROTARY: The conventional method of rotary drilling involving the rotation of a drill string and standard use of drilling fluid to penetrate the earth.

DISCHARGE HEAD: See Total Dynamic Head.

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.

DISINFECTION BY-PRODUCTS (DBPs): The products created due to the reaction of chlorine with organic materials (e.g. leaves, soil) present in raw water during the water treatment process. The EPA has determined that these DBPs can cause cancer. Chlorine is added to drinking water to kill or inactivate harmful organisms that cause various diseases. This process is called disinfection. However, chlorine is a very active substance and it reacts with naturally occurring substances to form compounds known as disinfection byproducts (DBPs). The most common DBPs formed when chlorine is used are trihalomethanes (THMs), and haloacetic acids (HAAs).

DISSOLVED OXYGEN: Can be added to zones within a lake or reservoir that would normally become anaerobic during periods of thermal stratification.

DISSOLUTION : The chemical and physical process of dissolving rock. Typically, limestone or carbonate rocks can be dissolved via the percolation or movement of groundwater that, in its infancy, is slightly acidic. As time goes on, the rock may also be physically worn away by the rapid movement of groundwater through the interconnected open spaces created by the initial chemical dissolving process.

DISTILLATION, REVERSE OSMOSIS AND FREEZING: Processes that can be used to remove minerals from the water.

DRAG BIT: A style of drill bit used in rotary drilling when soil or formation conditions are loosely consolidated and are comprised of fine-grained sediments.

DRAWDOWN: The change in water level from static to pumping level.

DRILL COLLAR: A section of the drill string that provides sufficient mass and diameter to maintain vertical borehole alignment and consistent borehole diameter.

DRILL FOAM: Surfactant used in air rotary drilling and well development.

DRILL PIPE: Sections of the drill string that are connected one to another in order to achieve a desired length while also providing a pathway for the circulation of drilling fluid.

DRILL STEM: The complete drill string or, in cable drilling, the equivalent of a drill collar.

DRILL STRING: The complete drilling assembly in rotary drilling including drill pipe, subs, collars, and bit.

DRILLER: A specially trained individual that operates the drilling rig.

DRILLING FLUID: Fluid circulated through the borehole in rotary drilling methods used to lift cuttings to the surface, provide borehole stability, and cool the bit. Drilling Fluid may consist of mud, water, air, foam, or other additives.

DRILLING PERMIT: A certificate of approval to drill and construct a well often required by the state or local regulating authority.

DRILLING PRESSURE: The pressure exerted within the borehole during drilling. The pressure required to circulate drilling fluid to the surface.

DRIVE BLOCK: A heavy collar that attaches over the drill pipe and is dropped successively to advance casing into the earth. Used primarily in cable tool or percussion drilling methods.

DRIVE CLAMP: A fitting that is attached to the top of a drill string or stem serving as a striking surface for driving casing into the earth.

DRIVE UNIT: The portion of a rotary rig that provides the rotation to the drill string. (ex – top drive or table drive unit). Also may be called the drive head.

DRIVING: The installation of a well or casing via forcing of it into the earth by repeated striking.

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.

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.

ELECTRON: The name of a negatively charged atomic particle.

ELEMENTARY BUSINESS PLAN: Technical Capacity, Managerial Capacity, and Financial Capacity make up the elementary business plan. To become a new public water system, an owner shall file an elementary business plan for review and approval by state environmental agency.

EMERGENCY RESPONSE TEAM: A local team that is thoroughly trained and equipped to deal with emergencies, e.g. chlorine gas leak. In case of a chlorine gas leak, get out of the area and notify your local emergency response team in case of a large uncontrolled chlorine leak.

ENHANCED COAGULATION: The process of joining together particles in water to help remove organic matter.

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.

ENTEROVIRUS: A virus whose presence may indicate contaminated water; a virus that may infect the gastrointestinal tract of humans.

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 *Khawkinea*. 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.

EVOLUTION: Any process of formation or growth; development: the evolution of a language; the evolution of the airplane. A product of such development; something evolved: The exploration of space is the evolution of decades of research.

Biology. Change in the gene pool of a population from generation to generation by such processes as mutation, natural selection, and genetic drift. A process of gradual, peaceful, progressive change or development, as in social or economic structure or institutions, a motion incomplete in itself, but combining with coordinated motions to produce a single action, as in a machine. A pattern formed by or as if by a series of movements: the evolutions of a figure skater.

F: The chemical symbol of Fluorine.

FAUCET WITH AN AERATOR: When collecting a water sample from a distribution system, a faucet with an aerator should not be used as a sample location.

FAULT: A break in the earth's crust where movement has occurred.

FAULTING: A geological process involving the breaking and displacement of rock or formation through movements within the earth's crust along a fault.

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.

FILTRATION: The process of passing water through materials with very small holes to strain out particles. Most conventional water treatment plants used filters composed of gravel, sand, and anthracite. These materials settle into a compact mass that forms very small holes. Particles are filtered out as treated water passes through these holes. These holes are small enough to remove microorganisms including algae, bacteria, and protozoans, but not viruses. Viruses are eliminated from drinking water through the process of disinfection using chlorine. A series of processes that physically removes particles from water. A water treatment step used to remove turbidity, dissolved organics, odor, taste and color.

FILTER CLOGGING: An inability to meet demand may occur when filters are clogging.

FILTRATION METHODS: The conventional type of water treatment filtration method includes coagulation, flocculation, sedimentation, and filtration. Direct filtration method is similar to conventional except that the sedimentation step is omitted. Slow sand filtration process does not require pretreatment, has a flow of 0.1 gallons per minute per square foot of filter surface area, and is simple to operate and maintain. The Diatomaceous earth method uses a thin layer of fine siliceous material on a porous plate. This type of filtration medium is only used for water with low turbidity. Sedimentation, adsorption, and biological action treatment methods are filtration processes that involve a number of interrelated removal mechanisms. Demineralization is primarily used to remove total dissolved solids from industrial wastewater, municipal water, and seawater.

FINISHED WATER: Treated drinking water that meets minimum state and federal drinking water regulations.

FLIGHTING: The spiral flanged drill pipe used in auger drilling.

FLOATING SUB: A collapsible section of drill pipe shorter than primary drill pipe. Used to provide a cushion between the drive unit and the drill string.

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. 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.

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.

FLOW MUST BE MEASURED: A recorder that measures flow is most likely to be located in a central location.

FLUORIDE: High levels of fluoride may stain the teeth of humans. This is called Mottling. This chemical must not be overfed due to a possible exposure to a high concentration of the chemical. The most important safety considerations to know about fluoride chemicals are that all fluoride chemicals are extremely corrosive. These are the substances most commonly used to furnish fluoride ions to water: Sodium fluoride, Sodium silicofluoride and Hydrofluosilicic acid.

FLUORIDE FEEDING: Always review fluoride feeding system designs and specifications to determine whether locations for monitoring readouts and dosage controls are convenient to the operation center and easy to read and correct.

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.

FORMATION: A series of layers, deposits, or bodies of rock, which are geologically similar and related in depositional environment or origin. A formation can be clearly distinguished relative to bounding deposits or formations due to its particular characteristics and composition.

FORMATION OF TUBERCLES: This condition is of the most concern regarding corrosive water effects on a water system. It is the creation of mounds of rust inside the water lines.

FRACTURE: A discrete break in a rock or formation.

FRACTURED AQUIFER: An aquifer within and otherwise massive block that has been made permeable due to the concentrated presence of fractures typically resultant of faulting or concentrated joints.

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.

GATE VALVE: The most common type of valve used in isolating a small or medium sized section of a distribution system and is the only linear valve used in water distribution. All the other valves are in the rotary classification.

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 TYPHOID: 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.

GEOTECHNICAL: Characteristics of soil, rock, or formation such as grain size, shear strength, porosity, and compressibility, etc. Of particular concern to a geologist or engineer relative to soil or aquifer characteristics.

GLOBE VALVE: The main difference between a globe valve and a gate valve is that a globe valve is designed as a controlling device.

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.

GRAINSIZE: The dimension of particle classifications such as gravel, sand, silt, and clay. Often based on the unified soil classification system.

GROUNDWATER: Water that percolates through and exists within saturated portions of the earth's crust and is replenished by the hydrologic cycle.

GROUT: A type of cement that is normally fine grained and used to effectively construct well seals and used in well abandonment. Grout may also be used to stabilize otherwise unstable boreholes, permitting continued drilling.

GT: Represents (Detention time) x (mixing intensity) in flocculation.

H₂SO₄: The molecular formula of Sulfuric acid.

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.

HALL EFFECT: Refers to the potential difference (Hall voltage) on the opposite sides of an electrical conductor through which an electric current is flowing, created by a magnetic field applied perpendicular to the current. Edwin Hall discovered this effect in 1879.

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 ($\text{CHCl}_2\text{CO}_2\text{H}$).

HAMMER BIT: The bit driven by the hammer to cut into rock or formation.

HAMMER: See Air Hammer

HARD ROCK: Consolidated formation or solid rock.

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.

HARTSHORN: The antler of a hart, formerly used as a source of ammonia. Ammonium carbonate.

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.

HERTZ: The term used to describe the frequency of cycles in an alternating current (AC) circuit.

HETEROTROPHIC PLATE COUNT: A test performed on drinking water to determine the total number of all types of bacteria in the water.

HF: The molecular formula of Hydrofluoric acid.

HIGH TURBIDITY CAUSING INCREASED CHLORINE DEMAND: May occur or be caused by the inadequate disinfection of water.

HOLLOW STEM (AUGER): An auger form of drilling in which the flighting is hollow.

HOLLOW STEM FLIGHT: The hollow spiral flanged drill pipe used on hollow stem auger rigs.

HOMOPOLAR: Of uniform polarity; not separated or changed into ions; not polar in activity. Electricity. unipolar.

HYDRAULIC CONDUCTIVITY: A primary factor in Darcy's Law, the measure of a soil or formations ability to transmit water, measured in gallons per day (gpd) See also Permeability and Darcy's Law.

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.

HYDROCHLORIC AND HYPOCHLOROUS ACIDS: HCL and HOCL 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 SULFIDE OR CHLORINE GAS: These chemicals can cause olfactory fatigue.

HYDROLOGIC CYCLE: (Water Cycle) The continual process of precipitation (rain and snowfall), evaporation (primarily from the oceans), percolation (recharge to groundwater), runoff (surface water), and transpiration (plants) constituting the renew ability and recycling of each component.

HYDROPHOBIC: Does not mix readily with water.

HYGROSCOPIC: Absorbing or attracting moisture from the air.

HYPOCHLORITE (OCL-) AND ORGANIC MATERIALS: Heat and possibly fire may occur when hypochlorite is brought into contact with an organic material.

HYPOLIMNION: The layer of water in a thermally stratified lake that lies below the thermocline, is noncirculating, and remains perpetually cold.

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.

IN SERIES: Several components being connected one to the other without a bypass, requiring each component to work dependent on the one before it.

INFILTRATION: The percolation of fluid into soil or formation. See also percolation.

INFECTIOUS PATHOGENS/MICROBES/GERMS: Are considered disease-producing bacteria, viruses and other microorganisms.

INFLATABLE PACKER: A rubber or fiber bladder device that is inflated to seal against either casing or borehole walls.

INFORMATION COLLECTION RULE: ICR EPA collected data required by the Information Collection Rule (May 14, 1996) to support future regulation of microbial contaminants, disinfectants, and disinfection byproducts. The rule was intended to provide EPA with information on chemical byproducts that form when disinfectants used for microbial control react with chemicals already present in source water (disinfection byproducts (DBPs)); disease-causing microorganisms (pathogens), including *Cryptosporidium*; and engineering data to control these contaminants.

INITIAL MONITORING YEAR: An initial monitoring year is the calendar year designated by the Department within a compliance period in which a public water system conducts initial monitoring at a point of entry.

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.

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.

IRON: Fe The elements iron and manganese are undesirable in water because they cause stains and promote the growth of iron bacteria.

IRON AND MANGANESE: Fe and Mn 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.

IRON BACTERIA: Perhaps the most troublesome consequence of iron and manganese in the water is they promote the growth of a group of microorganism known as Iron Bacteria.

IRON FOULING: You should look for an orange color on the resin and backwash water when checking an ion exchange unit for iron fouling

JARS (DRILLING JARS): Metal sections of a drill string that when released provide a jarring force or action to aid in removing drill string. Used primarily in cable tool or percussion drilling methods.

JETTING: The process of injecting high velocity streams of water and/or air through a system of nozzles or jets into the well screen and filter pack for well development.

KARST TOPOGRAPHY: The visual presence of karst on the surface.

KARST: The presence of caverns, voids, sink holes as characteristic features of a weathered limestone or other carbonate formation on or beneath the surface.

KELLY: A multi-faceted section of drill pipe driven by a kelly drive (table or top drive).

KILL = C X T: Where other factors are constant, the disinfecting action may be represented by: Kill=C x T. C= Chlorine T= Contact time.

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.

LACRIMATION: The secretion of tears, esp. in abnormal abundance Also, lachrymation, lachrimation.

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.
 $LSI = pH - pHs$

LEACHING: A chemical reaction between water and metals that allows for removal of soluble materials.

LEAD AND COPPER: Initial tap water monitoring for lead and copper must be conducted during 2 consecutive 6-month periods.

LIME: Is a chemical that may be added to water to reduce the corrosivity. When an operator adds lime to water, Calcium and magnesium become less soluble.

LIME SODA SOFTENING: In a lime soda softening process, to the pH of the water is raised to 11.0. In a lime softening process, excess lime is frequently added to remove Calcium and Magnesium Bicarbonate. The minimum hardness which can be achieved by the lime-soda ash process is 30 to 40 mg/L as calcium carbonate. The hardness due to noncarbonate hardness is most likely to determine the choice between lime softening and ion exchange to remove hardness.

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.

LINE SHAFT TURBINE: See vertical turbine.

LOGGED (LOGGING): The assessment and documentation of geological and water production data obtained while drilling progresses or following drilling through the use of borehole geophysical logging tools.

L.O.T.O.: Lock Out, Tag Out. 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.

M-ENDO BROTH: The coliform group is 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.

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.

MARBLE AND LANGELIER TESTS: Are used to measure or determine the corrosiveness of a water source.

MAXIMUM CONTAMINANT LEVEL (MCLs): The maximum allowable level of a contaminant that federal or state regulations allow in a public water system. If the MCL is exceeded, the water system must treat the water so that it meets the MCL.

MAXIMUM CONTAMINANT LEVEL GOAL (MCLG): The level of a contaminant at which there would be no risk to human health. This goal is not always economically or technologically feasible, and the goal is not legally enforceable.

MCL for TURBIDITY: Turbidity is undesirable because it causes health hazards. An MCL for turbidity was established by the EPA because turbidity does not allow for proper disinfection.

MEASURE CORROSION DAMAGE: A coupon such as a strip of metal and is placed to measure corrosion damage in the distribution system in a water main.

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.

MEDIUM WATER SYSTEM: More than 3,300 persons and 50,000 or fewer persons.

MEGGER: Is a portable instrument used to measure insulation resistance. The megger consists of a hand-driven DC generator and a direct reading ohm meter. Used to test the insulation resistance on a motor.

M-ENDO BROTH: The media shall be brought to the boiling point when preparing M-Endo broth to be used in the membrane filter test for total coliform.

METALIMNION: Thermocline, middle layer of a thermally stratified lake which is characterized by a rapid decrease in temperature in proportion to depth.

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)

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.

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.

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.

MICROBIOLOGICAL: Is a type of analysis in which a composite sample unacceptable.

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.

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.

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.

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.

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.

MOTTILING: High levels of fluoride may stain the teeth of humans.

M.S.D.S.: Material Safety Data Sheet. A safety document must an employer provide to an operator upon request.

MUD BALLS IN FILTER MEDIA: Is a possible result of an ineffective or inadequate filter backwash.

MUD CAKE: A film of mud drilling fluid that builds up on borehole walls adding to borehole stability and limits the groundwater's ability to enter the borehole while drilling.

MUD CAKING: The process of building up the mud cake.

MUD ENGINEER: A specially trained individual who's responsible for maintaining proper drilling fluid densities and viscosity.

MUD PIT: Single or multiple subsurface or surface containment system used for settling cuttings out of drilling fluid and for recirculation of drilling fluid.

MUD PUMP: A specially designed pump that can pass particles of mud and cuttings (drilling fluid) at variable pressures, serving as the primary component in a mud rotary drilling system (similar to a grout or cement pump).

MUD ROTARY: The method of rotary drilling with mud circulation as the drilling fluid.

MURIATIC ACID: An acid used to reduce pH and alkalinity. Also used to remove stain and scale.

MYCOTOXIN: A toxin produced by a fungus.

NaOCl: Is the molecular formula of Sodium hypochlorite.

NaOH: Is the molecular formula of Sodium hydroxide.

NASCENT: Coming into existence; emerging.

NATURAL GRAVEL PACK (NATURALLY PACKED): Refers to a well that has no gravel pack installed but is simply allowed to develop a filter pack composed of the aquifer particles itself. Usually coarse grained and hard rock aquifers are naturally packed.

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.

NITROGEN AND PHOSPHORUS: Pairs of elements and major plant nutrients that cause algae to grow.

NO₃⁻: The molecular formula of the Nitrate ion.

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.

NON-TRANSIENT, NON-COMMUNITY WATER SYSTEM: A water system which supplies water to 25 or more of the same people at least six months per year in places other than their residences. Some examples are schools, factories, office buildings, and hospitals which have their own water systems.

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. Nevertheless it is often used to describe solutions of acids or bases, in those cases it is implied that the normality refers to the H⁺ or OH⁻ ion. For example, 2 Normal sulfuric acid (H₂SO₄), means that the normality of H⁺ ions is 2, or that the molarity of the sulfuric acid is 1. Similarly for 1 Molar H₃PO₄ the normality is 3 as it contains three H⁺ ions.

NTNCWS: Non-transient non-community water system.

NTU (Nephelometric turbidity unit): A measure of the clarity or cloudiness of water.

O₃: The molecular formula of ozone.

OIL TUBE: A tubular enclosure that houses the line shaft and bearings of a vertical turbine pump. Oil is allowed to pass through the oil tube in order to lubricate the pumps drive shaft and bearings.

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.

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.

OVERBURDEN: Normally a thin loosely consolidated or unconsolidated sediment overlying competent formation.

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 Al₂O₃ that protects the foil from further corrosion.

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.

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 (O₃) is a triatomic molecule, consisting of three oxygen atoms. It is an allotrope of oxygen that is much less stable than the diatomic O₂. 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, O₃, 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):
$$2 \text{ O}_3 = 3 \text{ O}_2$$

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.

OZONE DOES NOT PROVIDE A RESIDUAL: One of the major drawbacks to using ozone as a disinfectant.

OZONE, CHLORINE DIOXIDE, UV, CHLORAMINES: These chemicals may be used as alternative disinfectants.

PAC: A disadvantage of using PAC is it is very abrasive and requires careful maintenance of equipment. One precaution that should be taken in storing PAC is that bags of carbon should not be stored near bags of HTH. Removes tastes and odors by adsorption only. Powdered activated carbon frequently used for taste and odor control because PAC is non-specific and removes a broad range of compounds. Jar tests and threshold odor number testing determines the application rate for powdered activated carbon. Powdered activated carbon, or PAC, commonly used for in a water treatment plant for taste and odor control. Powdered activated carbon may be used with some success in removing the precursors of THMs

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.

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).

PATHOGENS: Disease-causing pathogens; waterborne pathogens A pathogen may contaminate water and cause waterborne disease.

Pb: The chemical symbol of Lead.

PCE: 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.

PEAK DEMAND: The maximum momentary load placed on a water treatment plant, pumping station or distribution system.

PERCOLATION: The process of fluid penetrating or slowly flowing through soil, rock, or formation. See also infiltration.

PERCUSSION RIG: See Cable Tool.

PERFORATED SCREEN: Well screen that has openings mechanically cut into it.

PERFORMANCE CURVE: A graphical representation of a pumps efficiency relative to gpm and feet of head.

PEPTIDOGLYCAN: A polymer found in the cell walls of prokaryotes that consists of polysaccharide and peptide chains in a strong molecular network. Also called *mucopeptide*, *murein*.

PERMEATE: The term for water which has passed through the membrane of a reverse osmosis unit.

PERMEABILITY: A measure of a soil or formation's capacity to transmit water, typically in volume per time units. Equivalent to Darcy's hydraulic conductivity.

PERMEABLE: Soil or formation of which water can pass through.

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.

PHYSISORPTION: (Or physical adsorption) Is adsorption in which the forces involved are intermolecular forces (van der Waals forces) of the same kind as those responsible for the imperfection of real gases and the condensation of vapors, and which do not involve a significant change in the electronic orbital patterns of the species involved. The term van der Waals adsorption is synonymous with physical adsorption, but its use is not recommended.

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.

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.

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PIEZOMETRIC SURFACE: See potentiometric surface.

PILOT BIT: A bit used on auger rigs to cut a pilot hole ahead of the cutter head when drilling into more resistant formations.

PIPELINE APPURTENANCE: Pressure reducers, bends, valves, regulators (which are a type of valve), etc.

PITLESS ADAPTER: A fitting installed on a section of column pipe and well casing permitting piping from the well to be installed below grade. (Often requires a special permit for construction)

PLANKTON: The aggregate of passively floating, drifting, or somewhat motile organisms occurring in a body of water, primarily comprising microscopic algae and protozoa.

PLATFORM: The portion of the drilling rig where a driller and crew operate the drill rig.

PLUG: A removable cap installed behind the pilot and cutter bits on hollow stem auger flighting.

POINT OF ENTRY: POE.

POLLUTION: To make something unclean or impure. See Contaminated.

POLYPHOSPHATES: Chemicals that may be added to remove low levels of iron and manganese.

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.

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.

POST-CHLORINE: Where the water is chlorinated to make sure it holds a residual in the distribution system.

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.

POTENTIOMETRIC SURFACE: An imaginary surface representing the height a column of water will reach at any location within a confined aquifer. The measured surface of a confined aquifer related to the aquifer's pressure head.

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.

PERKINESIS: The aggregation resulting from random thermal motion of fluid molecules.

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 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.

PROTON, NEUTRON AND ELECTRON: Are the 3 fundamental particles of an atom.

PRODUCING ZONE: A specific productive interval.

PRODUCTIVE INTERVAL: The portion or portions of an aquifer in which significant water production is obtained within the well.

PROTIST: Any of a group of eukaryotic organisms belonging to the kingdom Protista according to some widely used modern taxonomic systems. The protists include a variety of unicellular, coenocytic, colonial, and multicellular organisms, such as the protozoans, slime molds, brown algae, and red algae. A unicellular protist in taxonomic systems in which the protists are considered to form a kingdom.

PROTOCTIST: Any of various unicellular eukaryotic organisms and their multicellular, coenocytic, or colonial descendants that belong to the kingdom Protocista according to some taxonomic systems. The protocists include the protozoans, slime molds, various algae, and other groups. In many new classification systems, all protocists are considered to be protists.

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.

PUBLIC NOTIFICATION: An advisory that EPA requires a water system to distribute to affected consumers when the system has violated MCLs or other regulations. The notice advises consumers what precautions, if any, they should take to protect their health.

PUBLIC WATER SYSTEM (PWS): Any water system which provides water to at least 25 people for at least 60 days annually. There are more than 170,000 PWSs providing water from wells, rivers and other sources to about 250 million Americans. The others drink water from private wells. There are differing standards for PWSs of different sizes and types.

PUMP SURGING: A process of well development whereby water is pumped nearly to the surface and then is allowed to fall back into the well. The process creates a backwashing action that cleans the well and nearby formation.

PUMPING LIFT: The height to which water must be pumped or lifted to, feet of head.

PWS: 3 types of public water systems. Community water system, non-transient non-community water system, transient non community water system.

RADIOCHEMICALS: (Or radioactive chemicals) Occur in natural waters. Naturally radioactive ores are particularly common in the Southwestern United States, and some streams and wells can have dangerously high levels of radioactivity. Total alpha and beta radioactivity and isotopes of radium and strontium are the major tests performed for radiochemicals. The federal drinking water standard for gross alpha radioactivity is set at 5 picocuries per liter.

RADIUS OF INFLUENCE: The distance away from a pumping well that water levels are affected by a wells cone of depression.

RAWHIDING: See Pump Surging.

RAW TURBIDITY: The turbidity of the water coming to the treatment plant from the raw water source.

RAW WATER: Water that has not been treated in any way; it is generally considered to be unsafe to drink.

REAGENT: A substance used in a chemical reaction to measure, detect, examine, or produce other substances.

REAM: The process of enlarging a borehole.

REAMER BIT: A special bit designed to ream existing boreholes.

RECHARGE: The infiltration component of the hydrologic cycle. Often used in the context of referring to: The infiltration of water back into an aquifer, resulting in the restoration of lost storage and water levels which had been decreased due to pumping and/or natural discharges from the aquifer.

RECIRCULATING SYSTEM: A system of constructed or surface mud pits that settle out cuttings from drilling fluid to be circulated back down the borehole.

RECORDER, FLOW: A flow recorder that measures flow is most likely to be located anywhere in the plant where a flow must be measured and in a central location.

RED WATER AND SLIME: Iron bacteria are undesirable in a water distribution system because of red water and slime complaints.

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).

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.

RESIDUAL DISINFECTION PROTECTION: A required level of disinfectant that remains in treated water to ensure disinfection protection and prevent recontamination throughout the distribution system (i.e., pipes).

REVERSE MUD ROTARY: A non-conventional drilling method in which drilling fluid is injected through the borehole annulus downward through the bit and circulated back to the surface through the drill string.

REVERSE OSMOSIS: Forces water through membranes that contain holes so small that even salts cannot pass through. Reverse osmosis removes microorganisms, organic chemicals, and inorganic chemicals, producing very pure water. For some people, drinking highly purified water exclusively can upset the natural balance of salts in the body. Reverse osmosis units require regular maintenance or they can become a health hazard.

RIBBED STABILIZER: A stabilizer or drill collar that has cutting ribs attached to its side. Ribs are normally installed in vertical or spiral arrangements.

ROLLER BIT: A rotary drill bit having rotating cutting heads.

ROTAMETER: The name of transparent tube with a tapered bore containing a ball is often used to measure the rate of flow of a gas or liquid.

ROTARY RIG: A conventional rotary drill rig. Can be either an air or mud rotary rig.

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.

RUNOFF: Surface water sources such as a river or lake are primarily the result of natural processes of runoff.

SAFE YIELD: A possible consequence when the "safe yield" of a well is exceeded and water continues to be pumped from a well, is land subsidence around the well will occur. Safe yield refers to a long-term balance between the water that is naturally and artificially recharged to an aquifer and the groundwater that is pumped out. When more water is removed than is recharged, the aquifer is described as being out of safe yield. When the water level in the aquifer then drops, we are said to be mining groundwater.

SALTS ARE ABSENT: Is a strange characteristic that is unique to water vapor in the atmosphere.

SAMPLE: The water that is analyzed for the presence of EPA-regulated drinking water contaminants. Depending on the regulation, EPA requires water systems and states to take samples from source water, from water leaving the treatment facility, or from the taps of selected consumers.

SAMPLING LOCATION: A location where soil or cuttings samples may be readily and accurately collected.

SAND, ANTHRACITE AND GARNET: Mixed media filters are composed of these three materials.

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.

SCHMUTZDECKE: German, "grime or filth cover", sometimes spelt schmutzedecke) is a complex biological layer formed on the surface of a slow sand filter. The schmutzdecke is the layer that provides the effective purification in potable water treatment, the underlying sand providing the support medium for this biological treatment layer. The composition of any particular schmutzdecke varies, but will typically consist of a gelatinous biofilm matrix of bacteria, fungi, protozoa, rotifera and a range of aquatic insect larvae. As a schmutzdecke ages, more algae tend to develop, and larger aquatic organisms may be present including some bryozoa, snails and annelid worms.

SCROLL AND BASKET: The two basic types of centrifuges used in water treatment.

SEAL: For wells: to abandon a well by filling up the well with approved seal material including cementing with grout from a required depth to the land surface.

SECONDARY DRINKING WATER STANDARDS: Non-enforceable federal guidelines regarding cosmetic effects (such as tooth or skin discoloration) or aesthetic effects (such as taste, odor, or color) of drinking water.

SECTIONAL MAP: The name of a map that provides detailed drawings of the distribution system's zones. Sometimes we call these quarter-sections.

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.

SESSILE: *Botany.* attached by the base, or without any distinct projecting support, as a leaf issuing directly from the stem. *Zoology.* permanently attached; not freely moving.

SETTLED SOLIDS: Solids that have been removed from the raw water by the coagulation and settling processes.

SHAKER: A device used in mud containment systems that vibrates various sized screens as drilling fluid passes through it, thereby separating cuttings from drilling fluid and providing a good sampling location.

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.

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.

SHROUD: A baffle or piece of pipe installed over a pump to force water to pass the pumps motor.

SIEVE ANALYSIS: The process of sifting soil or formation samples through a series of screens to determine percentages of particle sizes.

SINGLE PHASE POWER: The type of power used for lighting systems, small motors, appliances, portable power tools and in homes.

SINUSOID: A curve described by the equation $y = a \sin x$, the ordinate being proportional to the sine of the abscissa.

SINUSOIDAL: Mathematics. Of or pertaining to a sinusoid. Having a magnitude that varies as the sine of an independent variable: a sinusoidal current.

SLUDGE BASINS: After cleaning sludge basins and before returning the tanks into service the tanks should be inspected, repaired if necessary, and disinfected.

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 crushed rock and water.

SMALL WATER SYSTEM: 3,300 or fewer persons.

SOC: Synthetic organic chemical. 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.

SOIL MOISTURE: A relative consideration of the degree to which a soil is saturated.

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.

SOLAR DRYING BEDS OR LAGOONS: Are shallow, small-volume storage pond where sludge is concentrated and stored for an extended periods.

SOLAR DRYING BEDS, CENTRIFUGES AND FILTER PRESSES: Are procedures used in the dewatering of sludge.

SOLID, LIQUID AND VAPOR: 3 forms of matter.

SOLDER: A fusible alloy used to join metallic parts.

SOLID STEM (AUGER): An auger that is constructed of solid stem drill flights.

SPADNS: The lab reagent called SPADNS solution is used in performing the Fluoride test.

SPECIFIC CAPACITY (Sc): A measure of a well's pumping performance in gallons per minute per foot of drawdown.

SPIDER: A bearing or flange used in vertical turbine pumps to stabilize the drive shaft or shaft tube and seal column joints.

SPIRAL FLANGE: A continuous blade that wraps spirally around auger flighting.

SPIRIT OF HARTSHORN: A colorless, pungent, suffocating, aqueous solution of about 28.5 percent ammonia gas: used chiefly as a detergent, for removing stains and extracting certain vegetable coloring agents, and in the manufacture of ammonium salts.

SPLIT SPOON: A sampling device that is driven into the earth and operated by a wire line for the retrieval of soil or formation samples.

SPLIT FLOW CONTROL SYSTEM: This type of control system is to control the flow to each filter influent which is divided by a weir.

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.

STABLE: Reference to formation, soil, or sediments of sufficient strength to remain in place under its own weight and existing pressures.

STABILIZE: Actions taken to enhance borehole stability or vertical rotational when drilling.

STABILIZER: The portion of a drill string used to stabilize rotation.

STANDPIPE: A water tank that is taller than it is wide. Should not be found in low point.

STERILIZED GLASSWARE: The only type of glassware that should be used in testing for coliform bacteria.

STORAGE TANKS: Three types of water usage that determine the volume of a storage tank are fire suppression storage, equalization storage, and emergency storage. Equalization storage is the volume of water needed to supply the system for periods when demand exceeds supply. Generally, a water storage tank's interior coating (paint) protects the interior about 3-5 years.

S.T.P.: Standard temperature and pressure standard temperature and pressure the temperature of 0°C and pressure of 1 atmosphere, usually taken as the conditions when stating properties of gases.

STRATIFIED: Layered.

STUFFING BOX: That portion of the pump that houses the packing or mechanical seal.

SUB: A small section of drill pipe used to connect larger sections.

SUBMERSIBLE PUMP: A turbine pump that has the motor attached directly to it and therefore is operated while submerged.

SULFATE: Will readily dissolve in water to form an anion. Sulfate is a substance that occurs naturally in drinking water. Health concerns regarding sulfate in drinking water have been raised because of reports that diarrhea may be associated with the ingestion of water containing high levels of sulfate. Of particular concern are groups within the general population that may be at greater risk from the laxative effects of sulfate when they experience an abrupt change from drinking water with low sulfate concentrations to drinking water with high sulfate concentrations.

Sulfate in drinking water currently has a secondary maximum contaminant level (SMCL) of 250 milligrams per liter (mg/L), based on aesthetic effects (i.e., taste and odor). This regulation is not a federally enforceable standard, but is provided as a guideline for States and public water systems. EPA estimates that about 3% of the public drinking water systems in the country may have sulfate levels of 250 mg/L or greater. The Safe Drinking Water Act (SDWA), as amended in 1996, directs the U.S. Environmental Protection Agency (EPA) and the Centers for Disease Control and Prevention (CDC) to jointly conduct a study to establish a reliable dose-response relationship for the adverse human health effects from exposure to sulfate in drinking water, including the health effects that may be experienced by sensitive subpopulations (infants and travelers). SDWA specifies that the study be based on the best available peer-reviewed science and supporting studies, conducted in consultation with interested States, and completed in February 1999.

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^{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.

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.

SURFACE WATER SOURCES: Surface water sources such as a river or lake are primarily the result of Runoff.

SURFACE WATER: Water that is open to the atmosphere and subject to surface runoff; generally, lakes, streams, rivers.

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).

SUSCEPTIBILITY WAIVER: A waiver that is granted based upon the results of a vulnerability assessment.

SURGE-BLOCK: A disc shaped device that fits tightly into a well and is moved up and down to agitate the water column in order to develop a well.

SURGING: The process of purging a well rapidly for well development.

SWAB: See Surge-block.

SWING ARM: A large moveable arm on a bucket auger rig that pulls the bucket auger out away from the drilling rig for dumping.

SYNCHRONY: Simultaneous occurrence; synchronism.

TABLE DRIVE: A drilling rig that uses a rotating table within the platform to turn a kelly driven drill string.

TABLE: The back portion of a drill rig where the drill pipe is inserted (or driven if a table drive), adjacent to or within the driller's platform.

TAPPING VALVE: The name of the valve that is specifically designed for connecting a new water main to an existing main that is under pressure.

TARGET DEPTH: The proposed construction depth of a well prior to drilling.

TASTE AND ODORS: The primary purpose to use potassium permanganate in water treatment is to control taste and odors. Anaerobic water undesirable for drinking water purposes because of color and odor problems are more likely to occur under these conditions. Taste and odor problems in the water may happen if sludge and other debris are allowed to accumulate in a water treatment plant.

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. 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, this is a grab sample.

TELESCOPING KELLY: A kelly with successively smaller sized pipe within itself that drops out as a borehole is drilled. This permits that drilling may proceed without adding drill pipe. Normally found on bucket auger rigs.

TELESCOPING: The successive decrease in borehole size with depth.

THE RATE DECREASES: In general, when the temperature decreases, the chemical reaction rate decreases also.

THICKENING, CONDITIONING AND DEWATERING: Common processes that are utilized to reduce the volume of sludge.

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.

TITRIMETRIC: Chemistry. Using or obtained by titration. Titrimetrically, adverb.

TOP DRIVE: A rotary type drill head that moves freely up and down the rigs mast while driving the drill string.

TOROID: A surface generated by the revolution of any closed plane curve or contour about an axis lying in its plane. The solid enclosed by such a surface.

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.

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.

TRANSIENT, NON-COMMUNITY WATER SYSTEM: TNCWS A water system which provides water in a place such as a gas station or campground where people do not remain for long periods of time. These systems do not have to test or treat their water for contaminants which pose long-term health risks because fewer than 25 people drink the water over a long period. They still must test their water for microbes and several chemicals. A Transient Non-community Water System: Is not required to sample for VOC's.

TREATED WATER: Disinfected and/or filtered water served to water system customers. It must meet or surpass all drinking water standards to be considered safe to drink.

TRihalOMETHANES (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.

TRICONE BIT: A roller bit with three independent rolling bits with teeth or buttons that intermesh for efficient rock crushing and cutting.

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.

TURBINE PUMP: A pump that utilizes rotating impellers on a shaft that generate centrifugal force for pumping water.

UNCONFINED AQUIFER: An aquifer that exists under atmospheric pressure and is not confined.

UNCONSOLIDATED: Sediment that is not cemented or is loosely arranged.

UNDER-REAM: The process of reaming, from within the borehole, a section of an existing smaller borehole area.

UNSATURATED ZONE: That portion of the subsurface, including the capillary fringe that is not saturated but may contain water in both vapor and liquid form. See also Vadose Zone.

UNSTABLE: Sediment or other material that cannot exist without rapidly decomposing or collapsing in on itself. (ex. unconsolidated sediment)

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.

UNDER PRESSURE IN STEEL CONTAINERS: After chlorine gas is manufactured, it is primarily transported in steel containers.

UNIT FILTER RUN VOLUME (UFRV): One of the most popular ways to compare filter runs. This technique is the best way to compare water treatment filter runs.

VADOSE ZONE: A portion of the subsurface above the water table that is not saturated but contains water in both vapor and liquid form. The portion of the subsurface where water percolates through to the saturated zone. See also Unsaturated Zone.

VANE: That portion of an impeller that throws the water toward the volute.

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.

VIRION: A complete viral particle, consisting of RNA or DNA surrounded by a protein shell and constituting the infective form of a virus.

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.

VOC WAIVER: The longest term VOC waiver that a public water system using groundwater could receive is 9 years.

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. 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.

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.

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.

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.

WASHOUT: The rapid erosion of aquifer material from the borehole walls while a well is being drilled, which often results in a loss of circulation.

WATER COURSE: An opening within a cable tool drill string that allows fluid to flow in and out of the drill string thereby minimizing friction loss to the slurry.

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 PURVEYOR: The individuals or organization responsible to help provide, supply, and furnish quality water to a community.

WATER QUALITY: The 4 broad categories of water quality are: Physical, chemical, biological, radiological. Pathogens are disease causing organisms such as bacteria and viruses. A positive bacteriological sample indicates the presence of bacteriological contamination. Source water monitoring for lead and copper be performed when a public water system exceeds an action level for lead or copper.

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.

WATER TABLE: The measured water level surface of an unconfined aquifer.

WATER VAPOR: A characteristic that is unique to water vapor in the atmosphere is that water does not contain any salts.

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).

WATERSHED: An area that drains all of its water to a particular water course or body of water. The land area from which water drains into a stream, river, or reservoir.

WEATHERED: The existence of rock or formation in a chemically or physically broken down or decomposed state. Weathered material is in an unstable state.

WELL ABANDONMENT: The process of sealing a well by approved means. The filling of a well to the surface with cement grout.

WELL HEAD: The upper portion of the well that is constructed on the land surface, including the well manifold. Also a term used to refer to the area near the well that is subject to wellhead protection.

WELL HEAD PROTECTION: Programs designed to maintain the quality of groundwater used as public drinking water sources, by managing the land uses around the well field. A government program that encourages the limitation and elimination of activities, near and within a wells recharge area, which present a potential risk to the wells water supply.

WELL MANIFOLD: The piping, valves, and metering equipment used to connect the well to the distribution system, installed on the wellhead.

WELL SCREEN: A section of well casing that contains openings which permit water to enter the well but limit or prevent sediment from entering the well while pumping.

WELL SEAL: The watertight cap or seal installed within and between the well casing and pumping equipment. The metal or plastic plug or seal, which the pumping column rests on the top of casing.

WHOLE EFFLUENT TOXICITY: The total toxic effect of an effluent measured directly with a toxicity test.

YIELD: The volume of water measured in flow rates that are produced from the well.

ZONE OF AERATION: See Saturated Zone or Vadose Zone.

ZONE OF SATURATION: See Saturated Zone.



Top- Pre-sedimentation basin

Microorganism Appendix



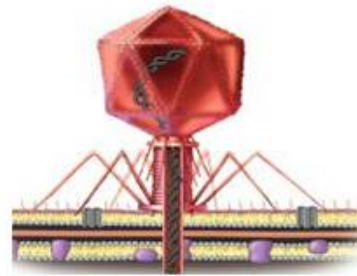
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(SPHERICAL)**



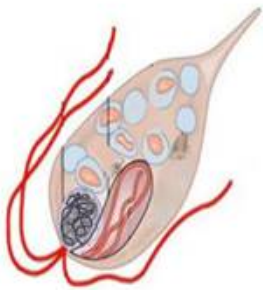
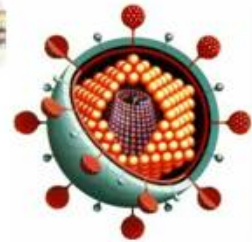
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(SPIRAL)**



**BACILLI
(ROD-SHAPED)**



VIRUSES



PROTOZOA

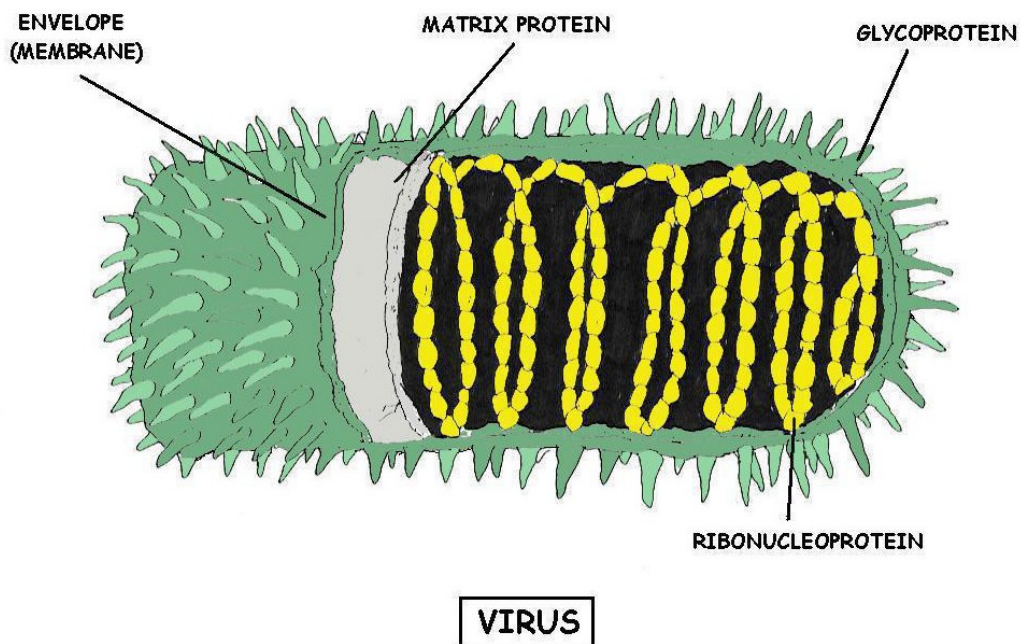


BACTERIA

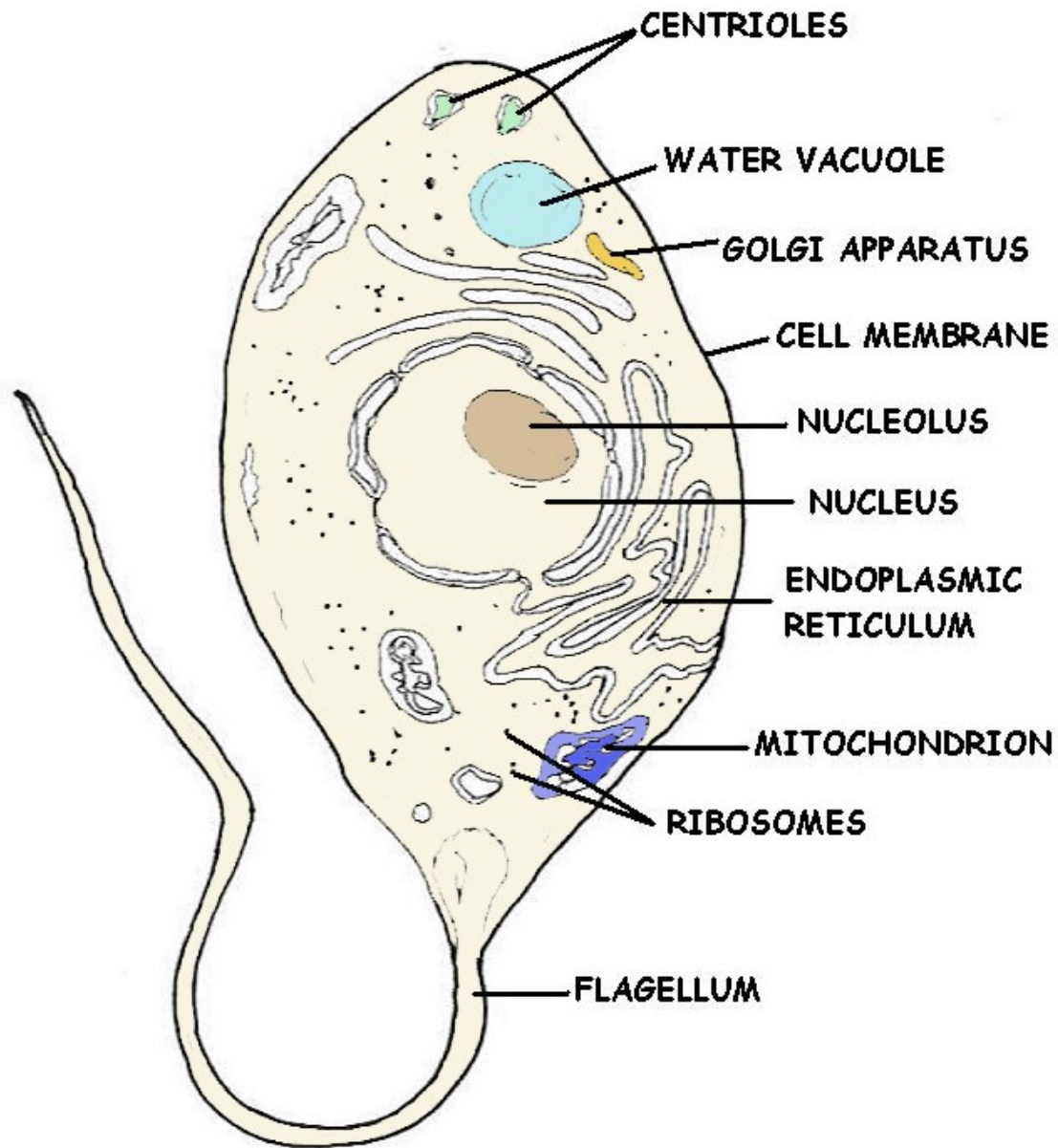
BACTERIA TYPES



This section will give a close-up and short explanation of the major microorganisms found in water and in wastewater.



Protozoa



PROTOZOAN CELL

Protozoa are around 10–50 micrometer, but can grow up to 1 mm and can easily be seen under a microscope. Protozoa exist throughout aqueous environments and soil. Protozoa occupy a range of trophic levels. As predators, they prey upon unicellular or filamentous algae, bacteria, and microfungi.

Protozoa play a role both as herbivores and as consumers in the decomposer link of the food chain. Protozoa also play a vital role in controlling bacteria populations and biomass. As components of the micro- and meiofauna, protozoa are an important food source for microinvertebrates. Thus, the ecological role of protozoa in the transfer of bacterial and algal production to successive trophic levels is important. Protozoa such as the malaria parasites (*Plasmodium* spp.), trypanosomes and leishmania are also important as parasites and symbionts of multicellular animals.

Most protozoa exist in 5 stages of life which are in the form of trophozoites and cysts. As cysts, protozoa can survive harsh conditions, such as exposure to extreme temperatures and harmful chemicals, or long periods without access to nutrients, water, or oxygen for a period of time. Being a cyst enables parasitic species to survive outside of the host, and allows their transmission from one host to another. When protozoa are in the form of trophozoites (Greek, tropho=to nourish), they actively feed and grow. The process by which the protozoa takes its cyst form is called encystation, while the process of transforming back into trophozoite is called excystation.

Protozoa can reproduce by binary fission or multiple fission. Some protozoa reproduce sexually, some asexually, and some both (e.g. *Coccidia*). An individual protozoan is hermaphroditic.

Classification

Protozoa were commonly grouped in the kingdom of Protista together with the plant-like algae and fungus-like water molds and slime molds. In the 21st-century systematics, protozoans, along with ciliates, mastigophorans, and apicomplexans, are arranged as animal-like protists. However, protozoans are neither Animalia nor Metazoa (with the possible exception of the enigmatic, moldy Myxozoa).

Sub-groups

Protozoa have traditionally been divided on the basis of their means of locomotion, although this is no longer believed to represent genuine relationships:

- * Flagellates (e.g. *Giardia lamblia*)
- * Amoeboids (e.g. *Entamoeba histolytica*)
- * Sporozoans (e.g. *Plasmodium knowlesi*)
- * Apicomplexa
- * Myxozoa
- * Microsporidia
- * Ciliates (e.g. *Balantidium coli*)

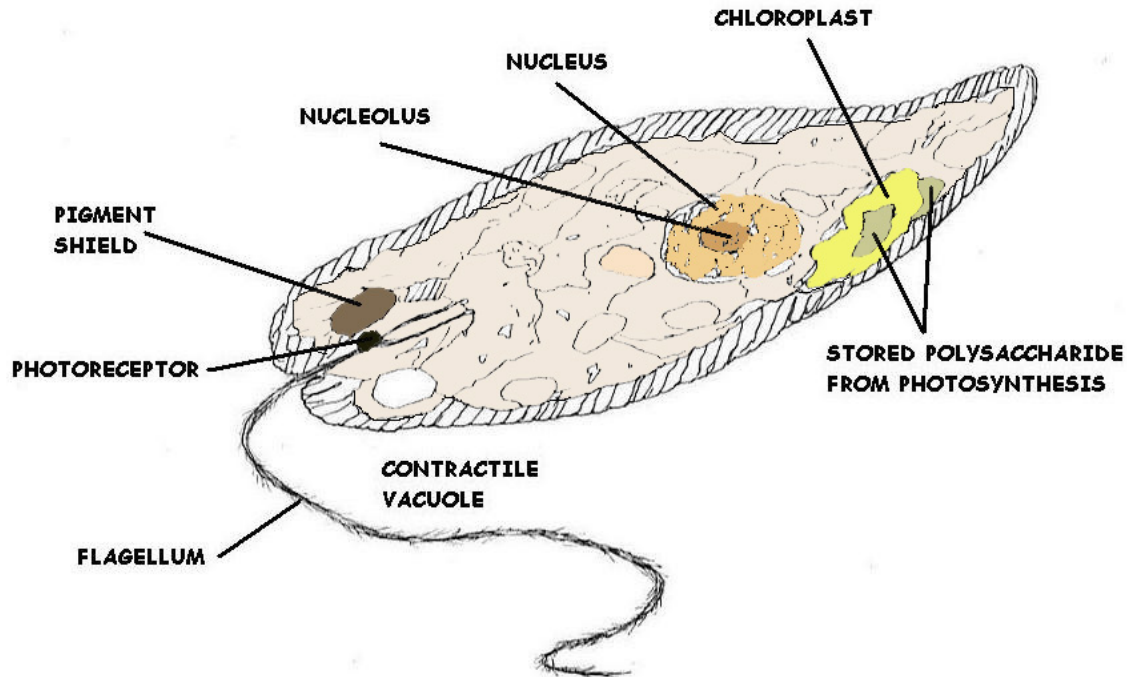
There are many ways that infectious diseases can spread. Pathogens usually have specific routes by which they are transmitted, and these routes may depend on the type of cells and tissue that a particular agent targets. For example, because cold viruses infect the respiratory tract, they are dispersed into the air via coughing and sneezing.

Once in the air, the viruses can infect another person who is unlucky enough to inhale air containing the virus particles.

Agents vary greatly in their stability in the environment. Some viruses may survive for only a few minutes outside of a host, while some spore-forming bacteria are extremely durable and may survive in a dormant state for a decade or more.

Protozoa Section

EUGLENA



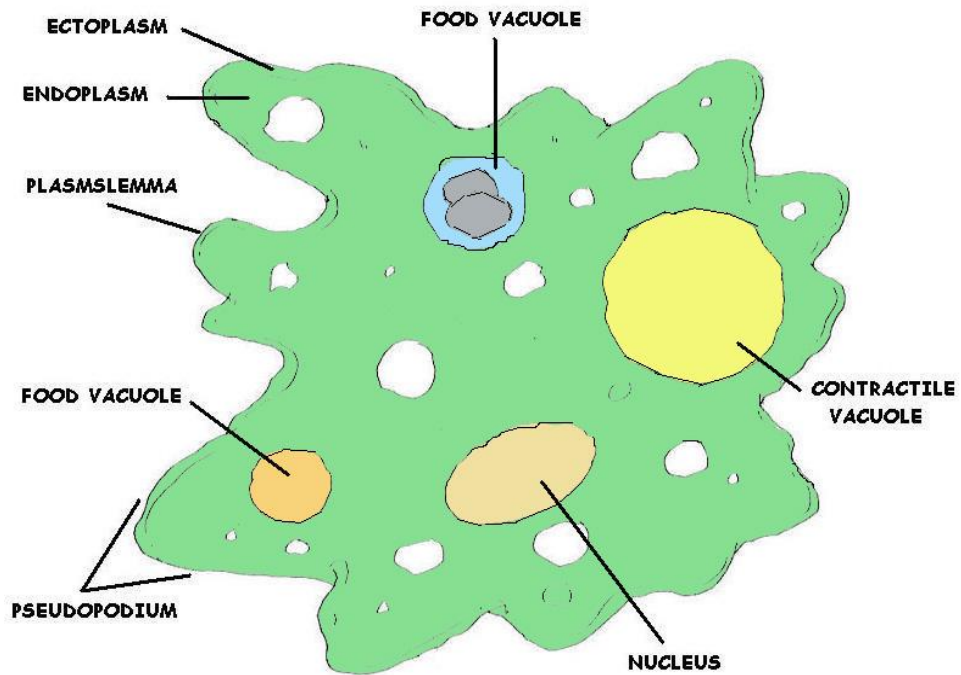
The diverse assemblage of organisms that carry out all of their life functions within the confines of a single, complex eukaryotic cell are called protozoa.

Paramecium, Euglena, and Amoeba are well-known examples of these major groups of organisms. Some protozoa are more closely related to animals, others to plants, and still others are relatively unique. Although it is not appropriate to group them together into a single taxonomic category, the research tools used to study any unicellular organism are usually the same, and the field of protozoology has been created to carry out this research. The unicellular photosynthetic protozoa are sometimes also called algae and are addressed elsewhere. This report considers the status of our knowledge of heterotrophic protozoa (protozoa that cannot produce their own food).

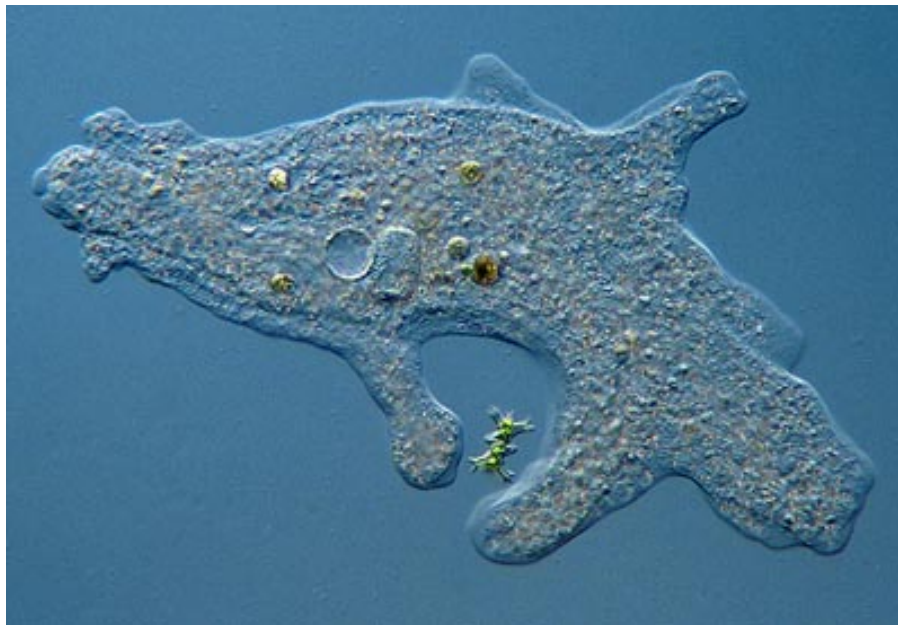
Free-living Protozoa

Protozoans are found in all moist habitats within the United States, but we know little about their specific geographic distribution. Because of their small size, production of resistant cysts, and ease of distribution from one place to another, many species appear to be cosmopolitan and may be collected in similar microhabitats worldwide (Cairns and Ruthven 1972). Other species may have relatively narrow limits to their distribution.

Marine ciliates inhabit interstices of sediment and beach sands, surfaces, deep sea and cold Antarctic environments, planktonic habitats, and the algal mats and detritus of estuaries and wetlands.



AMOEBA



Amoeba proteus, pseudopods slowly engulf the small desmid *Staurastrum*.

Amoebas

Amoebas (Phylum Rhizopoda) are unicellular protists that are able to change their shape constantly. Each species has its own distinct repertoire of shapes.

How does an amoeba locomote?

Amoebas locomote by way of cytoplasmic movement. (cytoplasm is the cell content around the nucleus of the cell) The amoeba forms pseudopods (false feet) with which they 'flow' over a surface. The cytoplasm not only flows, it also changes from a fluid into a solid state.

These pseudopods are also used to capture prey, they simply engulf the food. They can detect the kind of prey and use different 'engulfing tactics'.

The image from the last page shows several cell organelles. Left from the center we can see aspherical water expelling vesicle and just right of it, the single nucleus of this species can be seen. Other species may have many nuclei. The cell is full of brown food vacuoles and also contains small crystals.

Protozoa Information

Our actual knowledge of salinity, temperature, and oxygen requirements of marine protozoa is poor (although some groups, such as the foraminifera, are better studied than others), and even the broadest outlines of their biogeographic ranges are usually a mystery. In general, freshwater protozoan communities are similar to marine communities except the specialized interstitial fauna of the sand is largely missing. In freshwater habitats, the foraminifera and radiolaria common in marine environments are absent or low in numbers while testate amoebae exist in greater numbers. Relative abundance of species in the marine versus freshwater habitat is unknown.

Soil-dwelling protozoa have been documented from almost every type of soil and in every kind of environment, from the peat-rich soil of bogs to the dry sands of deserts. In general, protozoa are found in greatest abundance near the soil surface, especially in the upper 15 cm (6 in), but occasional isolates can be obtained at depths of a meter (yard) or more.

Protozoa do not constitute a major part of soil biomass, but in some highly productive regions such as forest litter, the protozoa are a significant food source for the microinvertebrates, with a biomass that may reach 20 g/m² of soil surface area there.

Environmental Quality Indicators

Polluted waters often have a rich and characteristic protozoan fauna. The relative abundance and diversity of protozoa are used as indicators of organic and toxic pollution (Cairns et al. 1972; Foissner 1987; Niederlehner et al. 1990; Curds 1992). Bick (1972), for example, provided a guide to ciliates that are useful as indicators of environmental quality of European freshwater systems, along with their ecological distribution with respect to parameters such as amount of organic material and oxygen levels.

Foissner (1988) clarified the taxonomy of European ciliates as part of a system for classifying the state of aquatic habitats according to their faunas.

Symbiotic Protozoa

Parasites

Protozoa are infamous for their role in causing disease, and parasitic species are among the best-known protozoa. Nevertheless, our knowledge has large gaps, especially of normally free-living protozoa that may become pathogenic in immunocompromised individuals. For example, microsporidia comprise a unique group of obligate, intracellular parasitic protozoa. Microsporidia are amazingly diverse organisms with more than 700 species and 80 genera that are capable of infecting a variety of plant, animal, and even other protist hosts.

They are found worldwide and have the ability to thrive in many ecological conditions. Until the past few years, their ubiquity did not cause a threat to human health, and few systematists worked to describe and classify the species. Since 1985, however, physicians have documented an unusual rise in worldwide infections in AIDS patients caused by four different genera of microsporidia (Encephalitozoon, Nosema, Pleistophora, and Enterocytozoon). According to the Centers for Disease Control in the United States, difficulties in identifying microsporidian species are impeding diagnosis and effective treatment of AIDS patients.

Protozoan Reservoirs of Disease

The presence of bacteria in the cytoplasm of protozoa is well known, whereas that of viruses is less frequently reported. Most of these reports simply record the presence of bacteria or viruses and assume some sort of symbiotic relationship between them and the protozoa. Recently, however, certain human pathogens were shown to not only survive but also to multiply in the cytoplasm of free-living, nonpathogenic protozoa. Indeed, it is now believed that protozoa are the natural habitat for certain pathogenic bacteria. To date, the main focus of attention has been on the bacterium *Legionella pneumophila*, the causative organism of Legionnaires' disease; these bacteria live and reproduce in the cytoplasm of some free-living amoebae (Curds 1992). More on this subject in the following pages.

Symbionts

Some protozoa are harmless or even beneficial symbionts. A bewildering array of ciliates, for example, inhabit the rumen and reticulum of ruminates and the cecum and colon of equids. Little is known about the relationship of the ciliates to their host, but a few may aid the animal in digesting cellulose.

Data on Protozoa

While our knowledge of recent and fossil foraminifera in the U.S. coastal waterways is systematically growing, other free-living protozoa are poorly known. There are some regional guides and, while some are excellent, many are limited in scope, vague on specifics, or difficult to use. Largely because of these problems, most ecologists who include protozoa in their studies of aquatic habitats do not identify them, even if they do count and measure them for biomass estimates (Taylor and Sanders 1991).

Parasitic protozoa of humans, domestic animals, and wildlife are better known although no attempt has been made to compile this information into a single source. Large gaps in our knowledge exist, especially for haemogregarines, microsporidians, and myxosporidians (see Kreier and Baker 1987).

Museum Specimens

For many plant and animal taxa, museums represent a massive information resource. This is not true for protozoa. In the United States, only the National Natural History Museum (Smithsonian Institution) has a reference collection preserved on microscope slides, but it does not have a protozoologist curator and cannot provide species' identification or verification services. The American Type Culture Collection has some protozoa in culture, but its collection includes relatively few kinds of protozoa.

Ecological Role of Protozoa

Although protozoa are frequently overlooked, they play an important role in many communities where they occupy a range of trophic levels. As predators upon unicellular or filamentous algae, bacteria, and microfungi, protozoa play a role both as herbivores and as consumers in the decomposer link of the food chain. As components of the micro- and meiofauna, protozoa are an important food source for microinvertebrates. Thus, the ecological role of protozoa in the transfer of bacterial and algal production to successive trophic levels is important.

Factors Affecting Growth and Distribution

Most free-living protozoa reproduce by cell division (exchange of genetic material is a separate process and is not involved in reproduction in protozoa). The relative importance for population growth of biotic versus chemical-physical components of the environment is difficult to ascertain from the existing survey data. Protozoa are found living actively in nutrient-poor to organically rich waters and in fresh water varying between 0°C (32°F) and 50°C (122°F). Nonetheless, it appears that rates of population growth increase when food is not constrained and temperature is increased (Lee and Fenchel 1972; Fenchel 1974; Montagnes et al. 1988).

Comparisons of oxygen consumption in various taxonomic groups show wide variation (Laybourn and Finlay 1976), with some aerobic forms able to function at extremely low oxygen tensions and to thereby avoid competition and predation.

Many parasitic and a few free-living species are obligatory anaerobes (grow without atmospheric oxygen). Of the free-living forms, the best known are the plagiopylid ciliates that live in the anaerobic sulfide-rich sediments of marine wetlands (Fenchel et al. 1977). The importance of plagiopylids in recycling nutrients to aerobic zones of wetlands is potentially great.

Because of the small size of protozoa, their short generation time, and (for some species) ease of maintaining them in the laboratory, ecologists have used protozoan populations and communities to investigate competition and predation.

The result has been an extensive literature on a few species studied primarily under laboratory conditions. Few studies have been extended to natural habitats with the result that we know relatively little about most protozoa and their roles in natural communities. Intraspecific competition for common resources often results in cannibalism, sometimes with dramatic changes in morphology of the cannibals (Giese 1973). Field studies of interspecific competition are few and most evidence for such species interactions is indirect (Cairns and Yongue 1977).

Contractile Vacuoles

Many protozoa have contractile vacuoles, which collect and expel excess water, and extrusomes, which expel material used to deflect predators or capture prey. In multicellular organisms, hormones are often produced in vesicles. In higher plants, most of a cell's volume is taken up by a central vacuole or tonoplast, which maintains its osmotic pressure. Many eukaryotes have slender motile projections, usually called flagella when long and cilia when short. These are variously involved in movement, feeding, and sensation. These are entirely distinct from prokaryotic flagella. They are supported by a bundle of microtubules arising from a basal body, also called a kinetosome or centriole, characteristically arranged as nine doublets surrounding two singlets. Flagella also may have hairs or mastigonemes, scales, connecting membranes, and internal rods. Their interior is continuous with the cell's cytoplasm.

Centrioles

Centrioles are often present even in cells and groups that do not have flagella. They generally occur in groups of one or two, called kinetids that give rise to various microtubular roots. These form a primary component of the cytoskeletal structure, and are often assembled over the course of several cell divisions, with one flagellum retained from the parent and the other derived from it. Centrioles may also be associated in the formation of a spindle during nuclear division. Some protists have various other microtubule-supported organelles. These include the radiolaria and heliozoa, which produce axopodia used in flotation or to capture prey, and the haptophytes, which have a peculiar flagellum-like organelle called the haptoneura.

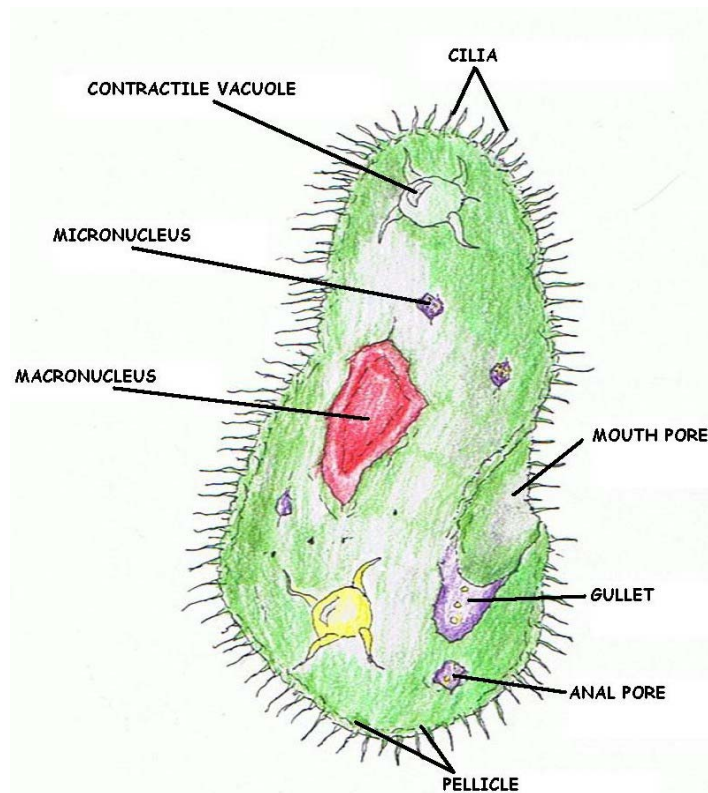


Figure 1. A diagram of *Paramecium* sp. with major organelles indicated.



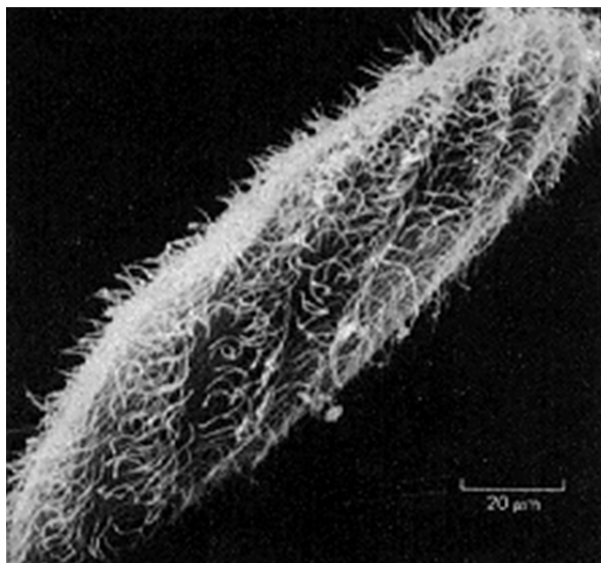
Contractile Vacuoles

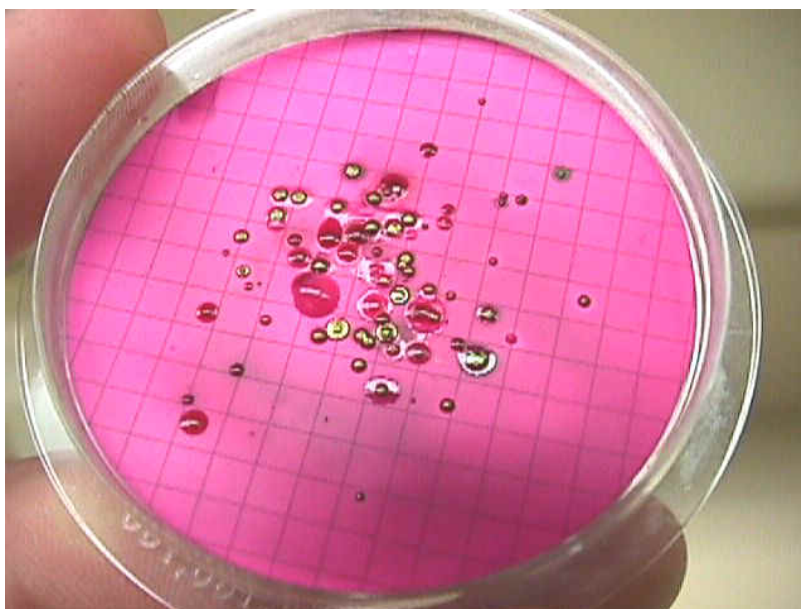
Figure 2. The contractile vacuole when full (top) and after contraction (bottom).

Paramecium

Members of the genus *Paramecium* are single-celled, freshwater organisms in the kingdom Protista. They exist in an environment in which the osmotic concentration in their external environment is much lower than that in their cytoplasm. More specifically, the habitat in which they live is **hypotonic** to their cytoplasm. As a result of this, *Paramecium* is subjected to a continuous influx of water, as water diffuses inward to a region of higher osmotic concentration.

If *Paramecium* is to maintain homeostasis, water must be continually pumped out of the cell (against the osmotic gradient) at the same rate at which it moves in. This process, known as **osmoregulation**, is carried out by two organelles in *Paramecium* known as **contractile vacuoles** (Figures 1 and 2).





Coliform Bacteria on a Petri Dish. Bottom photo, SimPlate for HPC counts. IDEXX's SimPlate for HPC method is used for the quantification of heterotrophic plate count (HPC) in water. It is based on the Multiple Enzyme Technology which detects viable bacteria in water by testing for the presence of key enzymes known to be present in these little organisms. This technique uses enzyme substrates that produce a blue fluorescence when metabolized by waterborne bacteria. The sample and media are added to a SimPlate Plate, incubated and then examined for fluorescing wells. The number of wells corresponds to a Most Probable Number (MPN) of total bacteria in the original sample. The MPN values generated by the SimPlate for HPC method correlate with the Pour Plate method using the Total Plate Count Agar incubated at 35°C for 48 hours as described in *Standard Methods for the Examination of Water and Wastewater*, 19th Edition.



Protozoan Diseases

Protozoan pathogens are larger than bacteria and viruses, but still microscopic. They invade and inhabit the gastrointestinal tract. Some parasites enter the environment in a dormant form, with a protective cell wall called a “**cyst**.” The cyst can survive in the environment for long periods of time and be extremely resistant to conventional disinfectants such as chlorine. Effective filtration treatment is therefore critical to removing these organisms from water sources.

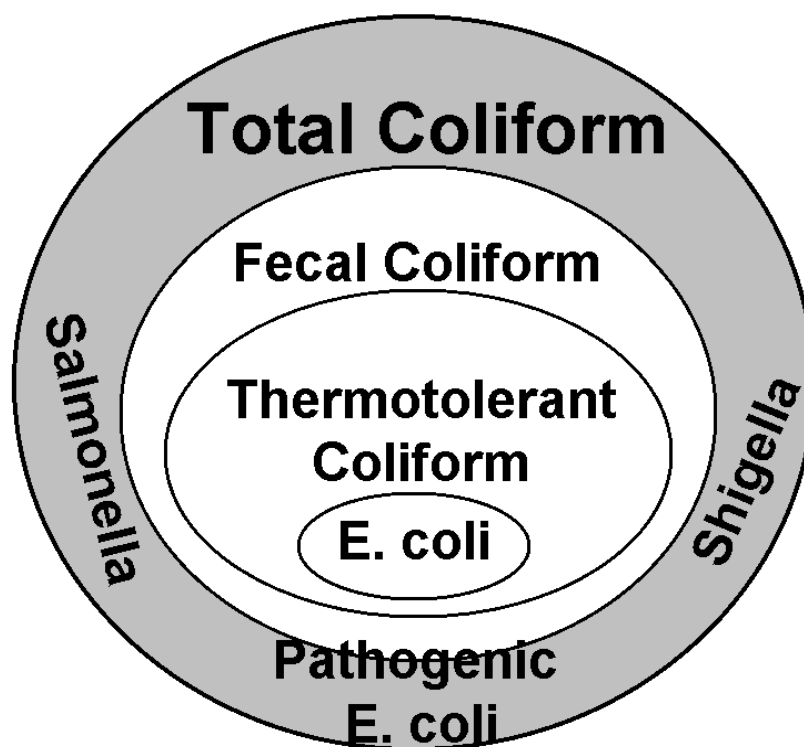
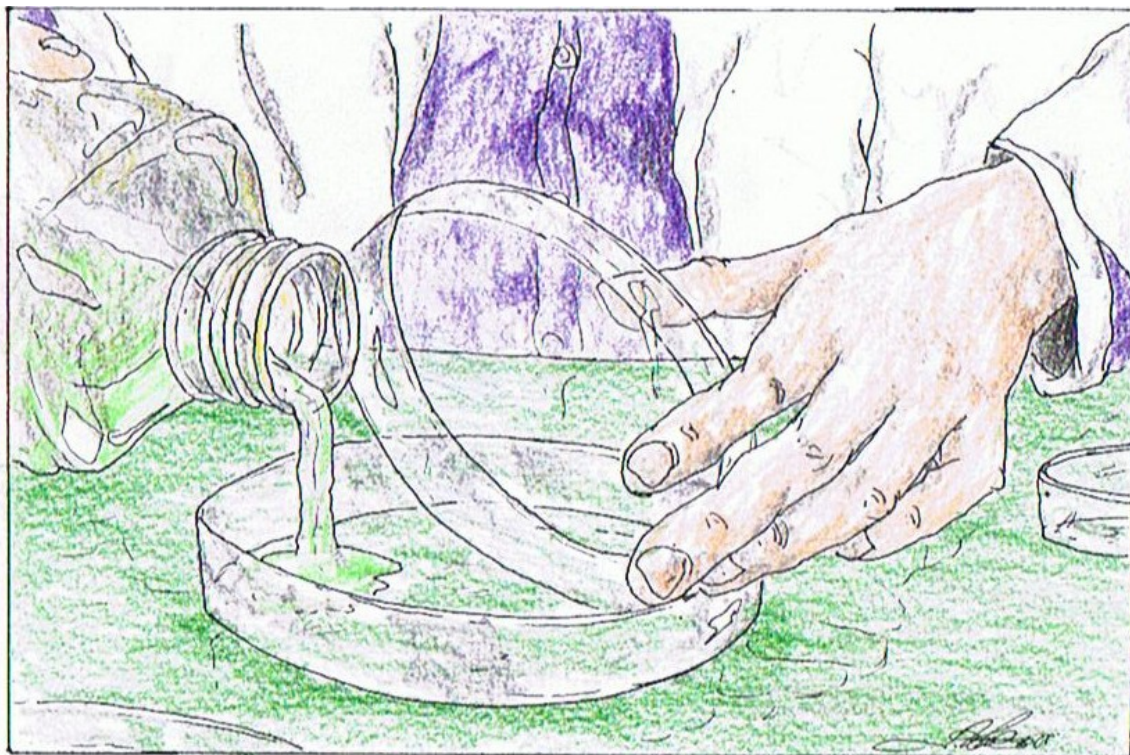
Giardiasis

Giardiasis is a commonly reported protozoan-caused disease. It has also been referred to as “**backpacker’s disease**” and “**beaver fever**” because of the many cases reported among hikers and others who consume untreated surface water. Symptoms include chronic diarrhea, abdominal cramps, bloating, frequent loose and pale greasy stools, fatigue and weight loss. The incubation period is 5-25 days or longer, with an average of 7-10 days. Many infections are asymptomatic (no symptoms). Giardiasis occurs worldwide. Waterborne outbreaks in the United States occur most often in communities receiving their drinking water from streams or rivers without adequate disinfection or a filtration system. The organism, ***Giardia lamblia***, has been responsible for more community-wide outbreaks of disease in the U.S. than any other pathogen. Drugs are available for treatment but are not 100% effective.

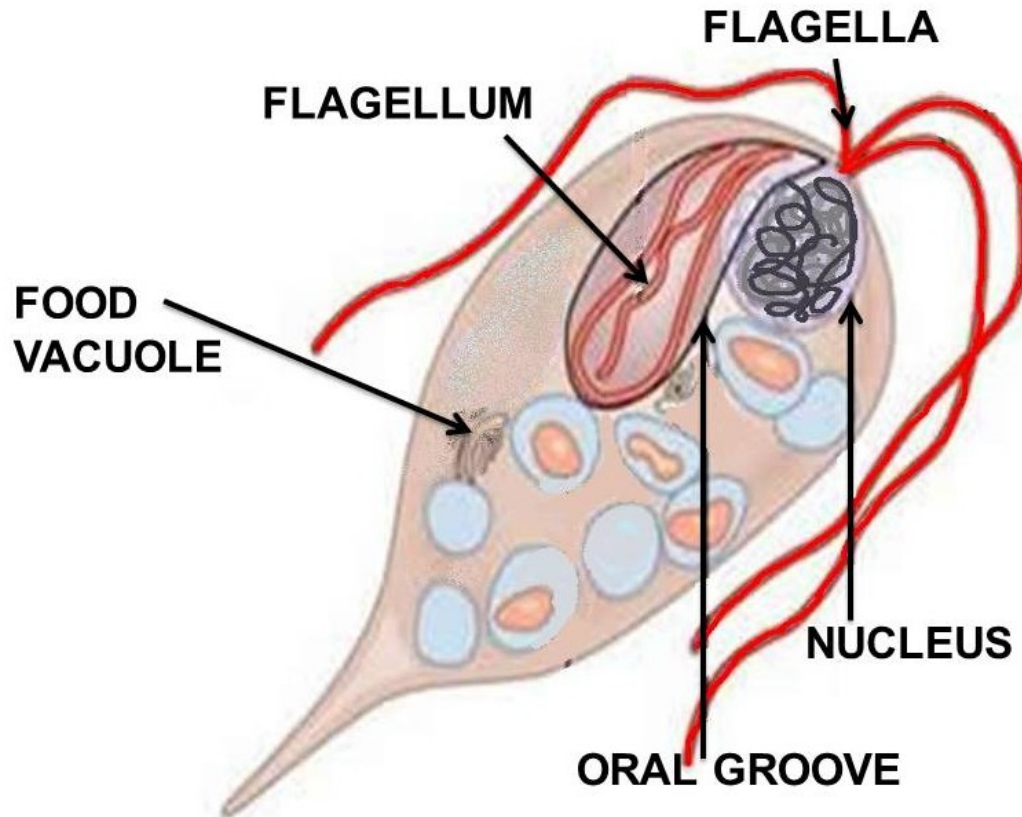
Cryptosporidiosis

Cryptosporidiosis is an example of a protozoan disease that is common worldwide, but was only recently recognized as causing human disease. The major symptom in humans is diarrhea, which may be profuse and watery. The diarrhea is associated with cramping abdominal pain. General malaise, fever, anorexia, nausea, and vomiting occur less often. Symptoms usually come and go, and end in fewer than 30 days in most cases. The incubation period is 1-12 days, with an average of about seven days. ***Cryptosporidium*** organisms have been identified in human fecal specimens from more than 50 countries on six continents. The mode of transmission is fecal-oral, either by person-to-person or animal-to-person. There is no specific treatment for ***Cryptosporidium*** infections.

All of these diseases, with the exception of hepatitis A, have one symptom in common: diarrhea. They also have the same mode of transmission, fecal-oral, whether through person-to-person or animal-to-person contact, and the same routes of transmission, being either foodborne or waterborne. Although most pathogens cause mild, self-limiting disease, on occasion, they can cause serious, even life threatening illness. Particularly vulnerable are persons with weak immune systems such as those with HIV infections or cancer. By understanding the nature of waterborne diseases, the importance of properly constructed, operated and maintained public water systems becomes obvious. While water treatment cannot achieve sterile water (no microorganisms), the goal of treatment must clearly be to produce drinking water that is as pathogen-free as possible at all times. For those who operate water systems with inadequate source protection or treatment facilities, the potential risk of a waterborne disease outbreak is real. For those operating systems that currently provide adequate source protection and treatment, operating and maintaining the system at a high level on a continuing basis is critical to prevent disease.



Giardia Lamblia



GIARDIA LAMBLIA

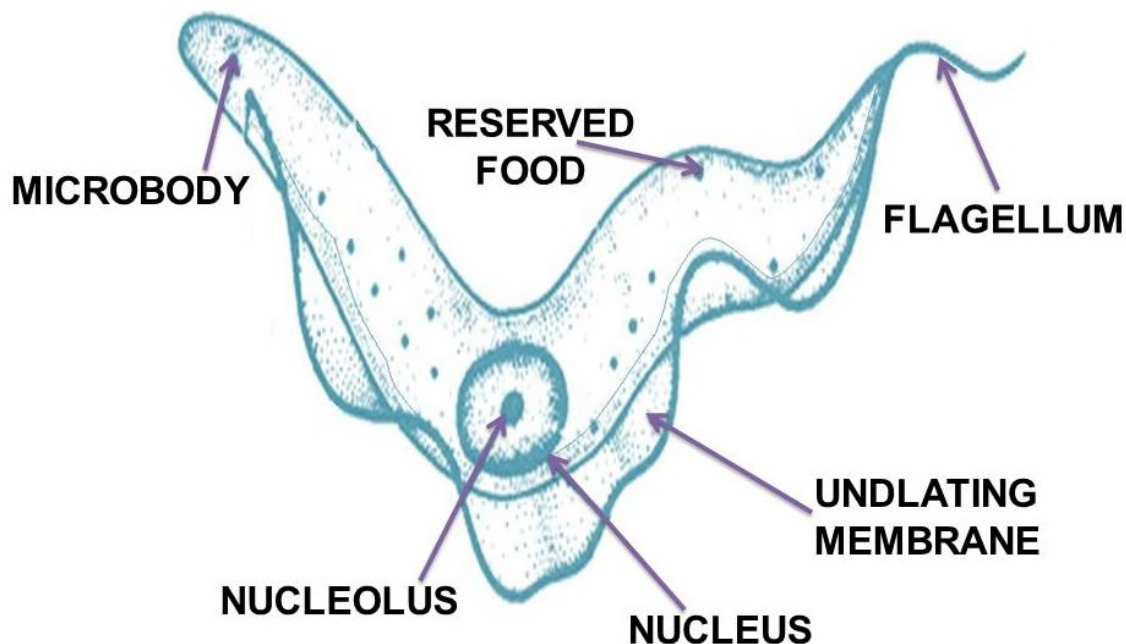
Giardia lamblia (synonymous with *Lamblia intestinalis* and *Giardia duodenalis*) is a flagellated protozoan parasite that colonizes and reproduces in the small intestine, causing giardiasis. The giardia parasite attaches to the epithelium by a ventral adhesive disc, and reproduces via binary fission. 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.

Giardia infection can occur through ingestion of dormant cysts in contaminated water, or by the fecal-oral route (through poor hygiene practices). The Giardia cyst can survive for weeks to months in cold water and therefore can be present in contaminated wells and water systems, and even clean-looking mountain streams, as well as city reservoirs, as the Giardia cysts are resistant to conventional water treatment methods, such as chlorination and ozonolysis. Zoonotic transmission is also possible, and therefore Giardia infection is a concern for people camping in the wilderness or swimming in contaminated streams or lakes, especially the artificial lakes formed by beaver dams (hence the popular name for giardiasis, "Beaver Fever"). As well as water-borne sources, fecal-oral transmission can also occur, for example in day care centers, where children may have poorer hygiene practices.

Those who work with children are also at risk of being infected, as are family members of infected individuals. Not all Giardia infections are symptomatic, so some people can unknowingly serve as carriers of the parasite.

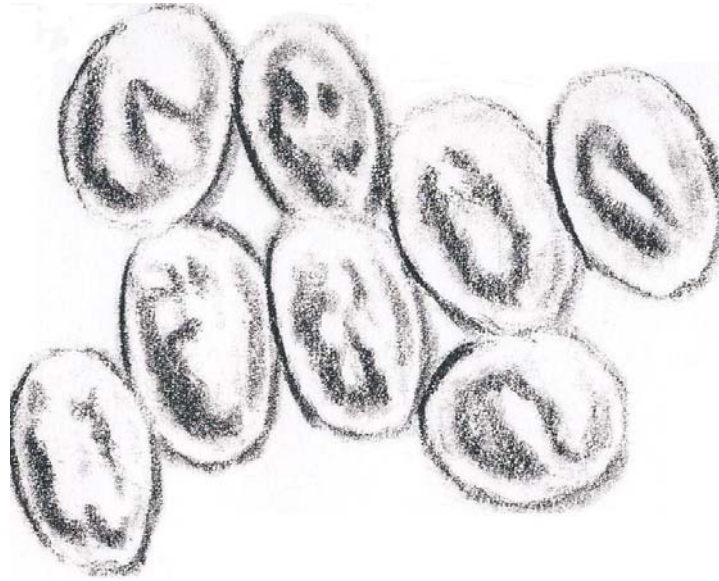
The life cycle begins with a non-infective cyst being excreted with feces of an infected individual. Once out in the environment, the cyst becomes infective. A distinguishing characteristic of the cyst is 4 nuclei and a retracted cytoplasm. Once ingested by a host, the trophozoite emerges to an active state of feeding and motility. After the feeding stage, the trophozoite undergoes asexual replication through longitudinal binary fission. The resulting trophozoites and cysts then pass through the digestive system in the feces. While the trophozoites may be found in the feces, only the cysts are capable of surviving outside of the host.

Distinguishing features of the trophozoites are large karyosomes and lack of peripheral chromatin, giving the two nuclei a halo appearance. Cysts are distinguished by a retracted cytoplasm. This protozoa lacks mitochondria, although the discovery of the presence of mitochondrial remnant organelles in one recent study "indicate that Giardia is not primitively amitochondrial and that it has retained a functional organelle derived from the original mitochondrial endosymbiont"



PROTOZOAN PARASITE

Cryptosporidium

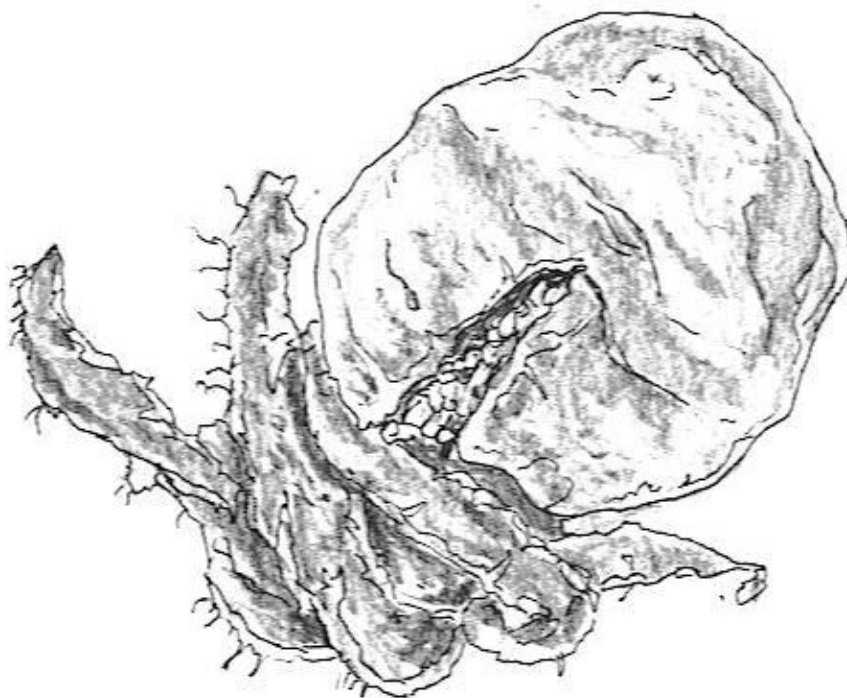


Cryptosporidium is a protozoan pathogen of the Phylum Apicomplexa and causes a diarrheal illness called cryptosporidiosis. Other apicomplexan pathogens include the malaria parasite Plasmodium, and Toxoplasma, the causative agent of toxoplasmosis. Unlike Plasmodium, which transmits via a mosquito vector, 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.

A number of species of Cryptosporidium infect mammals. In humans, the main causes of disease are *C. parvum* and *C. hominis* (previously *C. parvum* genotype 1). *C. canis*, *C. felis*, *C. meleagridis*, and *C. muris* can also cause disease in humans. In recent years, cryptosporidiosis has plagued many commercial Leopard gecko breeders. Several species of the Cryptosporidium family (*C. serpentes* and others) are involved, and outside of geckos it has been found in monitor lizards, iguanas, tortoises as well as several snake species.

Cryptosporidiosis is typically an acute short-term infection but can become severe and non-resolving in children and immunocompromised individuals. The parasite is transmitted by environmentally hardy cysts (oocysts) that, once ingested, excyst in the small intestine and result in an infection of intestinal epithelial tissue.

The genome of *Cryptosporidium parvum* was sequenced in 2004 and was found to be unusual amongst Eukaryotes in that the mitochondria seem not to contain DNA. A closely-related species, *C. hominis*, also has its genome sequence available. CryptoDB.org is a NIH-funded database that provides access to the Cryptosporidium genomics data sets.



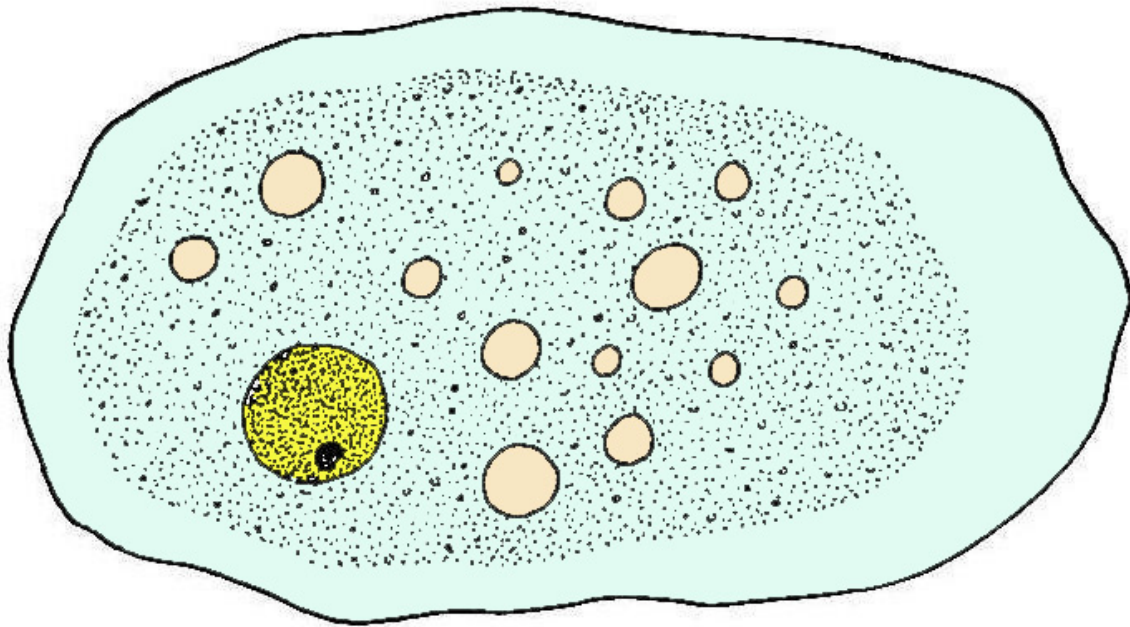
CRYPTO-PARVUM

When *C. parvum* was first identified as a human pathogen, diagnosis was made by a biopsy of intestinal tissue (Keusch, *et al.*, 1995). However, this method of testing can give false negatives due to the "patchy" nature of the intestinal parasitic infection (Flanigan and Soave, 1993). Staining methods were then developed to detect and identify the oocysts directly from stool samples. The modified acid-fast stain is traditionally used to most reliably and specifically detect the presence of cryptosporidial oocysts.

There have been six major outbreaks of cryptosporidiosis in the United States as a result of contamination of drinking water (Juranek, 1995). One major outbreak in Milwaukee in 1993 affected over 400,000 persons. Outbreaks such as these usually result from drinking water taken from surface water sources such as lakes and rivers (Juranek, 1995). Swimming pools and water park wave pools have also been associated with outbreaks of cryptosporidiosis. Also, untreated groundwater or well water public drinking water supplies can be sources of contamination.

The highly environmentally resistant cyst of *C. parvum* allows the pathogen to survive various drinking water filtrations and chemical treatments such as chlorination. Although municipal drinking water utilities may meet federal standards for safety and quality of drinking water, complete protection from cryptosporidial infection is not guaranteed. In fact, *all* waterborne outbreaks of cryptosporidiosis have occurred in communities where the local utilities met all state and federal drinking water standards (Juranek, 1995).

Entamoeba histolytica

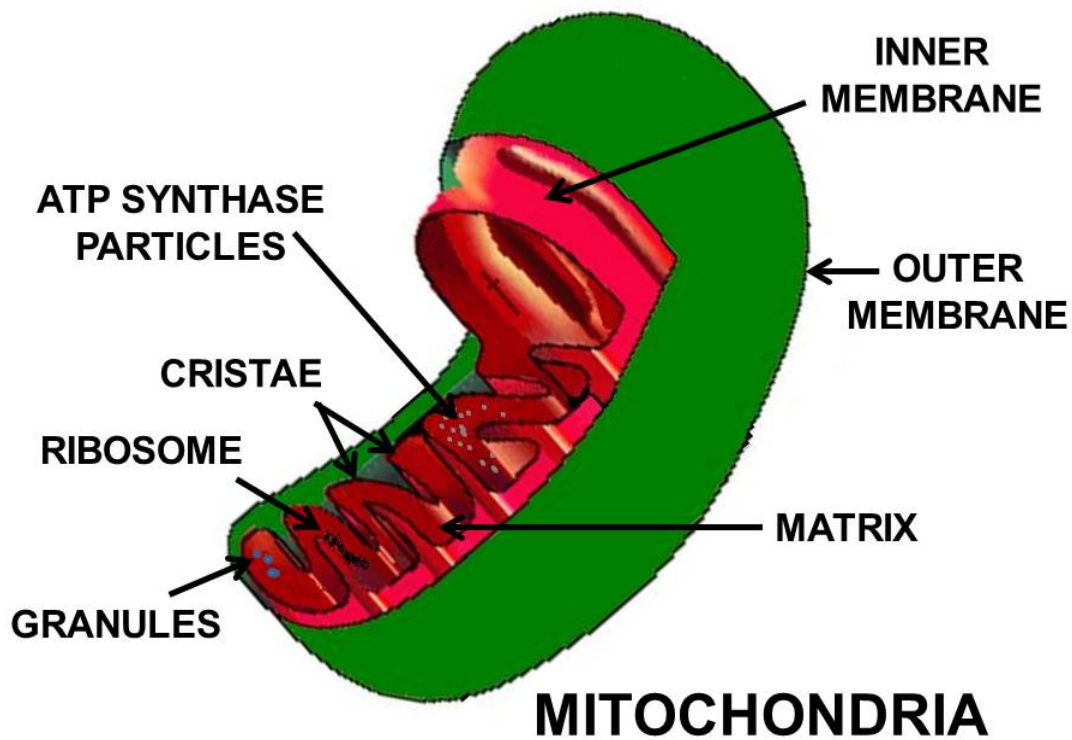


Entamoeba histolytica, another water-borne pathogen, can cause diarrhea or a more serious invasive liver abscess. When in contact with human cells, these amoebae are cytotoxic. There is a rapid influx of calcium into the contacted cell, it quickly stops all membrane movement save for some surface blebbing. 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.

On average, about one in 10 people who are infected with *E. histolytica* becomes sick from the infection. The symptoms often are quite mild and can include loose stools, stomach pain, and stomach cramping. Amebic dysentery is a severe form of amebiasis associated with stomach pain, bloody stools, and fever. Rarely, *E. histolytica* invades the liver and forms an abscess. Even less commonly, it spreads to other parts of the body, such as the lungs or brain.

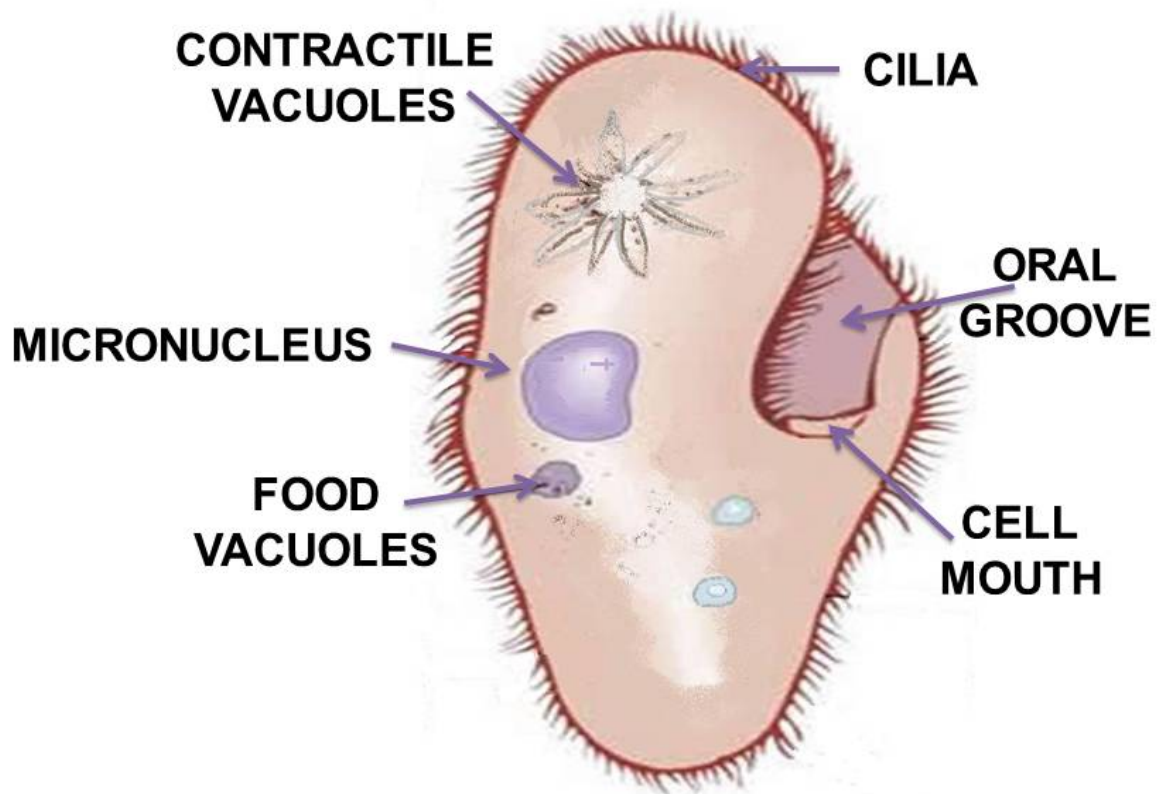
Scientific classification

Domain: Eukaryota
Phylum: Amoebozoa
Class: Archamoebae
Genus: *Entamoeba*
Species: *E. histolytica*



Mitochondria

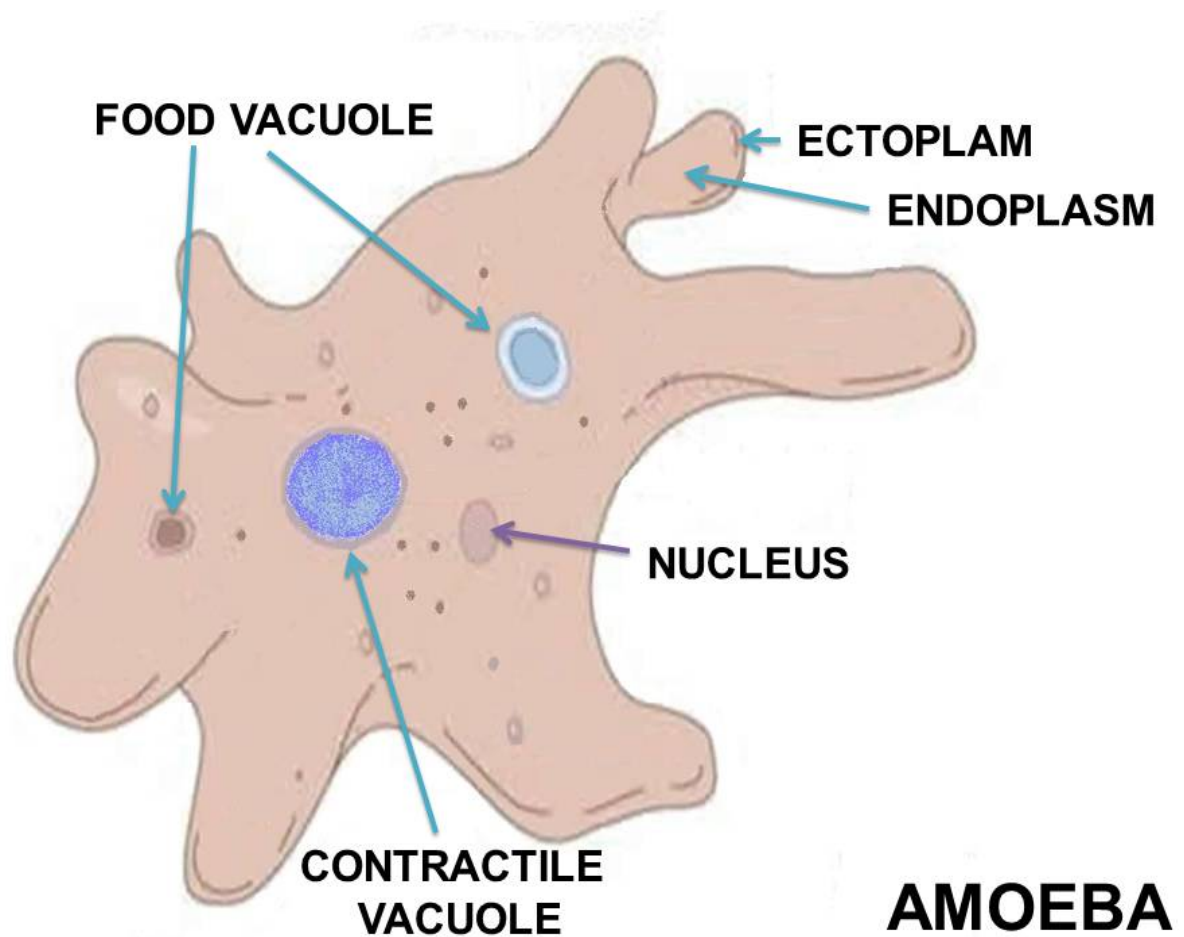
The bacterial cell is surrounded by a lipid membrane, or cell membrane, which encloses the contents of the cell and acts as a barrier to hold nutrients, proteins and other essential components of the cytoplasm within the cell. As they are prokaryotes, bacteria do not tend to have membrane-bound organelles in their cytoplasm and thus contain few large intracellular structures. They consequently lack a nucleus, mitochondria, chloroplasts and the other organelles present in eukaryotic cells, such as the Golgi apparatus and endoplasmic reticulum.



PARAMECIUM

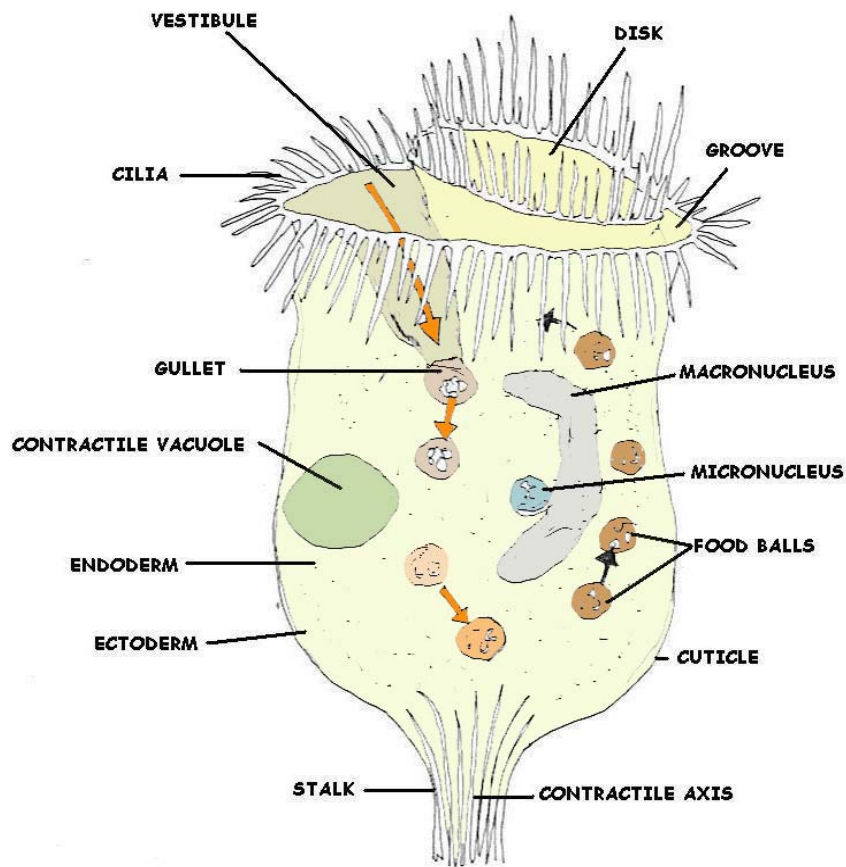
Paramecia

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).



Amoeba

Amoeba (sometimes amœba 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.



VORTICELLA

(TYPE OF PROTOZOAN FOUND IN STAGNANT WATER)

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.

Domain: Eukaryota

Phylum: Ciliophora

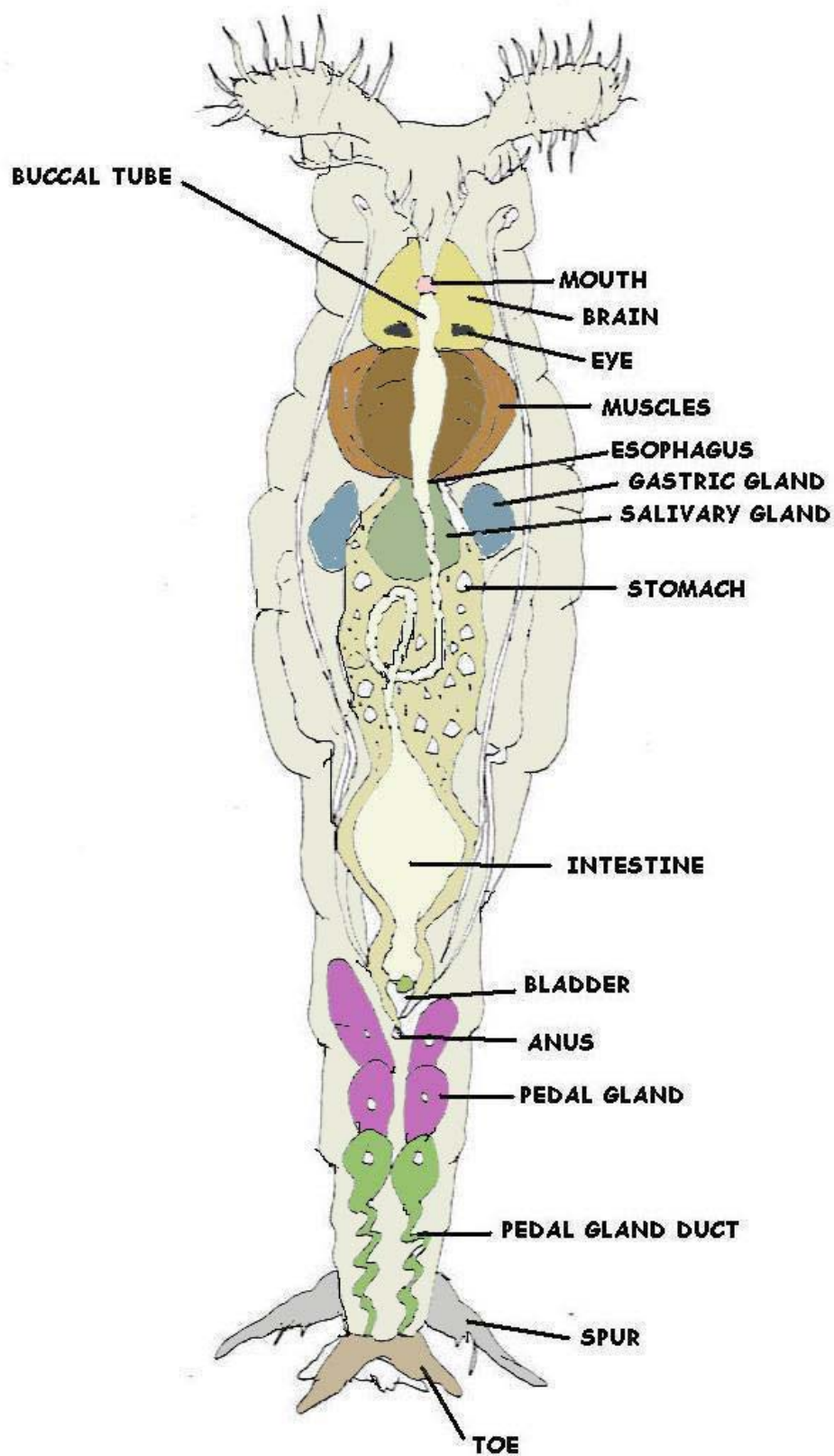
Class: Oligohymenophorea

Subclass: Peritrichia

Order: Sessilida

Family: Vorticellidae

Genus: Vorticella



ROTIFER

Rotifer

The rotifers make up a phylum of microscopic and near-microscopic pseudocoelomate animals. They were first described by John Harris in 1696 (Hudson and Gosse, 1886). Leeuwenhoek is mistakenly given credit for being the first to describe rotifers but Harris had produced sketches in 1703. Most rotifers are around 0.1-0.5 mm long, and are common in freshwater throughout the world with a few saltwater species. Rotifers may be free swimming and truly planktonic, others move by inch worming along the substrate, whilst some are sessile, living inside tubes or gelatinous holdfasts. About 25 species are colonial (e.g. *Sinantharina semibullata*), either sessile or planktonic.

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.

Like many other microscopic animals, adult rotifers frequently exhibit eutely - they have a fixed number of cells within a species, usually on the order of one thousand. Males in the class Monogononta may be either present or absent depending on the species and environmental conditions. In the absence of males, reproduction is by parthenogenesis and results in clonal offspring that are genetically identical to the parent. Individuals of some species form two distinct types of parthenogenetic eggs; one type develops into a normal parthenogenetic female, while the other occurs in response to a changed environment and develops into a degenerate male that lacks a digestive system, but does have a complete male reproductive system that is used to inseminate females thereby producing fertilized 'resting eggs'. Resting eggs develop into zygotes that are able to survive extreme environmental conditions such as may occur during winter or when the pond dries up. These eggs resume development and produce a new female generation when conditions improve again. The life span of monogonont females varies from a couple of days to about three weeks.

Bdelloid rotifers are unable to produce resting eggs, but many can survive prolonged periods of adverse conditions after desiccation. This facility is termed anhydrobiosis, and organisms with these capabilities are termed anhydrobionts. Under drought conditions, bdelloid rotifers contract into an inert form and lose almost all body water; when rehydrated, however, they resume activity within a few hours. Bdelloids can survive the dry state for prolonged periods, with the longest well-documented dormancy being nine years. While in other anhydrobionts, such as the brine shrimp, this desiccation tolerance is thought to be linked to the production of trehalose, a non-reducing disaccharide (sugar), bdelloids apparently lack the ability to synthesize trehalose. Bdelloid rotifer genomes contain two or more divergent copies of each gene. Four copies of hsp82 are, for example, found. Each is different and found on a different chromosome, excluding the possibility of homozygous sexual reproduction.

Waterborne Diseases

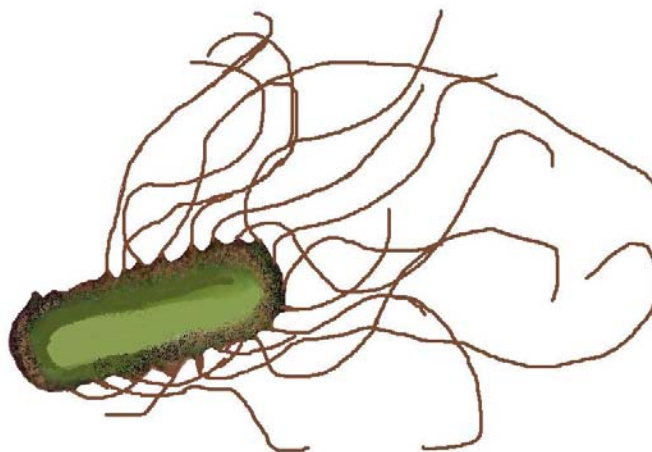
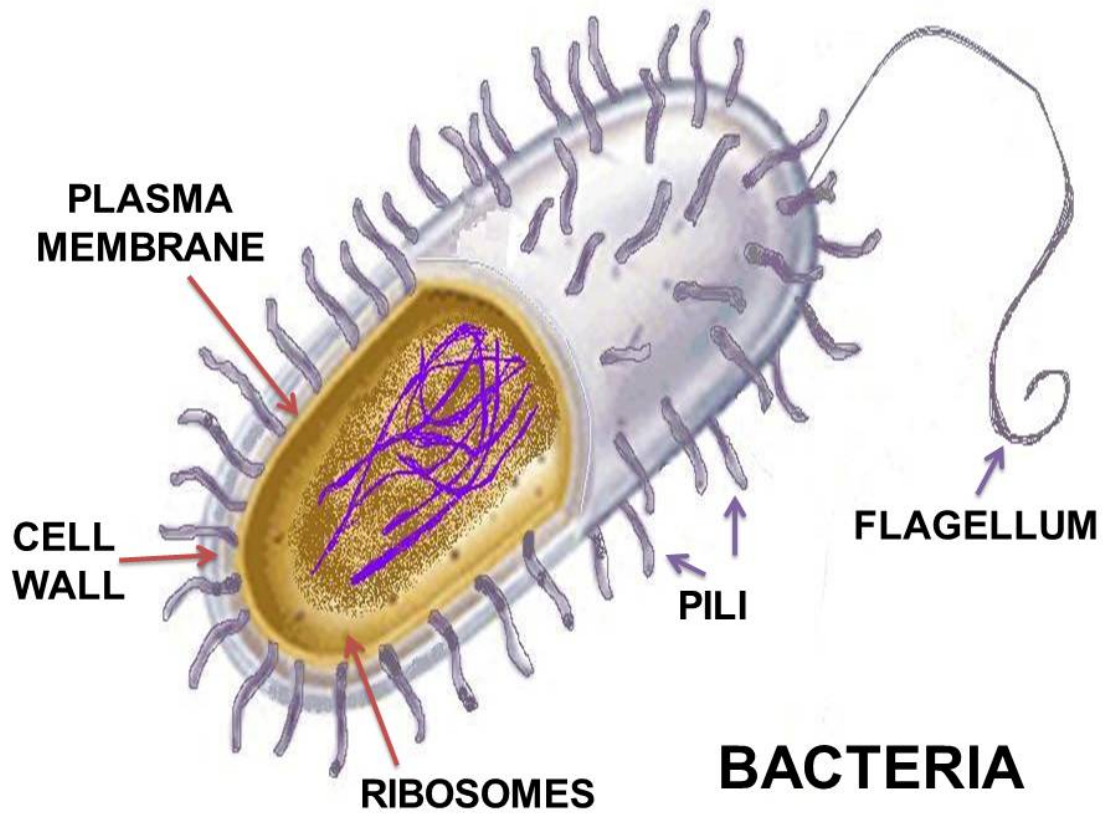
Name	Causative organism	Source of organism	Disease
Viral gastroenteritis	Rotavirus (mostly in young children)	Human feces	Diarrhea or vomiting
Norwalk Agent	Noroviruses (genus <i>Norovirus</i> , family <i>Caliciviridae</i>) ^{*1}	Human feces; also, shellfish; lives in polluted waters	Diarrhea and vomiting
Salmonellosis	Salmonella (bacterium)	Animal or human feces	Diarrhea or vomiting
Gastroenteritis <i>Escherichia coli</i>	-- <i>E. coli</i> O1 57:H7 (bacterium): Other <i>E. coli</i> organisms:	Human feces	Symptoms vary with type caused
Typhoid	Salmonella typhi (bacterium)	Human feces, urine	Inflamed intestine, enlarged spleen, high temperature—sometimes fatal
Shigellosis	Shigella (bacterium)	Human feces	Diarrhea
Cholera	Vibrio choleras (bacterium)	Human feces; also, shellfish; lives in many coastal waters	Vomiting, severe diarrhea, rapid dehydration, mineral loss—high mortality
Hepatitis A	Hepatitis A virus	Human feces; shellfish grown in polluted waters	Yellowed skin, enlarged liver, fever, vomiting, weight loss, abdominal pain—low mortality, lasts up to four months
Amebiasis	Entamoeba histolytica (protozoan)	Human feces	Mild diarrhea, dysentery, extra intestinal infection
Giardiasis	Giardia lamblia (protozoan)	Animal or human feces	Diarrhea, cramps, nausea, and general weakness — lasts one week to months
Cryptosporidiosis	Cryptosporidium parvum	Animal or human feces	Diarrhea, stomach pain — lasts (protozoan) days to weeks

Notes:

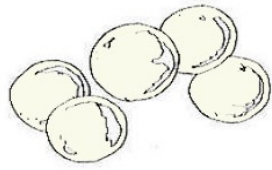
*1 <http://www.cdc.gov/ncidod/dvrd/revb/gastro/norovirus.htm>

<http://www.cdc.gov/mmwr/preview/mmwrhtml/rr5009a1.htm>

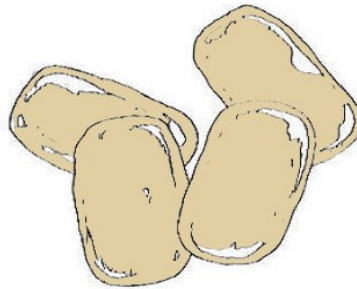
Bacteria Section



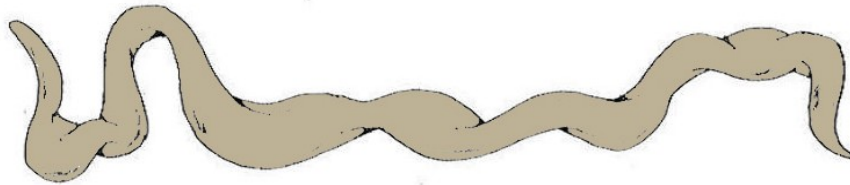
Peritrichous Bacteria



**COCCI
(SPHERICAL)**



**BACILLI
(ROD-SHAPED)**



**SPIRILLI
(SPIRAL)**

BACTERIA TYPES

Microbiologists broadly classify bacteria according to their shape: spherical, rod-shaped, and spiral-shaped. Pleomorphic bacteria can assume a variety of shapes. Bacteria may be further classified according to whether they require oxygen (aerobic or anaerobic) and how they react to a test with Gram's stain. Bacteria in which alcohol washes away Gram's stain are called gram-negative, while bacteria in which alcohol causes the bacteria's walls to absorb the stain are called gram-positive.



**COLORLESS FILAMENTOUS
SULFUR BACTERIA**

Shigella dysenteriae



SHIGELLA DYSENTERIAE

Shigella dysenteriae is a species of the rod-shaped bacterial genus *Shigella*. *Shigella* can cause shigellosis (bacillary dysentery). *Shigellae* are Gram-negative, non-spore-forming, facultatively anaerobic, non-motile bacteria.

S. dysenteriae, spread by contaminated water and food, causes the most severe dysentery because of its potent and deadly Shiga toxin, but other species may also be dysentery agents. *Shigella* infection is typically via ingestion (fecal–oral contamination); depending on age and condition of the host as few as ten bacterial cells can be enough to cause an infection. *Shigella* causes dysentery that result in the destruction of the epithelial cells of the intestinal mucosa in the cecum and rectum. Some strains produce enterotoxin and Shiga toxin, similar to the verotoxin of *E. coli* O157:H7. Both Shiga toxin and verotoxin are associated with causing hemolytic uremic syndrome.

Shigella invades the host through epithelial cells of the large intestine. Using a Type III secretion system acting as a biological syringe, the bacterium injects IpaD protein into cell, triggering bacterial invasion and the subsequent lysis of vacuolar membranes using IpaB and IpaC proteins. It utilizes a mechanism for its motility by which its IcsA protein triggers actin polymerization in the host cell (via N-WASP recruitment of Arp2/3 complexes) in a "rocket" propulsion fashion for cell-to-cell spread.

The most common symptoms are diarrhea, fever, nausea, vomiting, stomach cramps, and straining to have a bowel movement. The stool may contain blood, mucus, or pus (e.g. dysentery). In rare cases, young children may have seizures. Symptoms can take as long as a week to show up, but most often begin two to four days after ingestion. Symptoms usually last for several days, but can last for weeks. *Shigella* is implicated as one of the pathogenic causes of reactive arthritis worldwide.



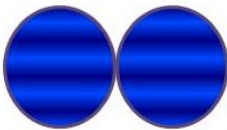
Coccus



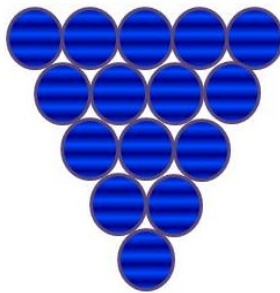
Bacillus



Spirillum



Diplo-



Staphylo-



Strepto-

Bacteria Types

Type	Characteristics
Acetic acid	Rod-shaped, gram-negative, aerobic; highly tolerant of acidic conditions; generate organic acids
Actinomycete	Rod-shaped or filamentous, gram-positive, aerobic; common in soils; essential to growth of many plants; source of much of original antibiotic production in pharmaceutical industry
Coccoid	Spherical, sometimes in clusters or strings, gram-positive, aerobic and anaerobic; resistant to drying and high-salt conditions; <i>Staphylococcus</i> species common on human skin, certain strains associated with toxic shock syndrome
Coryneform	Rod-shaped, form club or V shapes, gram-positive, aerobic; found in wide variety of habitats, particularly soils; highly resistant to drying; include <i>Arthrobacter</i> , among most common forms of life on earth
Endospore-forming	Usually rod-shaped, can be gram-positive or gram-negative; have highly adaptable, heat-resistant spores that can go dormant for long periods, possibly thousands of years; include <i>Clostridium</i> (anaerobic) and <i>Bacillus</i> (aerobic)
Enteric	Rod-shaped, gram-negative, aerobic but can live in certain anaerobic conditions; produce nitrite from nitrate, acids from glucose; include <i>Escherichia coli</i> , <i>Salmonella</i> (over 1000 types), and <i>Shigella</i>
Gliding	Rod-shaped, gram-negative, mostly aerobic; glide on secreted slimy substances; form colonies, frequently with complex fruiting structures
Lactic acid	Gram-positive, anaerobic; produce lactic acid through fermentation; include <i>Lactobacillus</i> , essential in dairy product formation, and <i>Streptococcus</i> , common in humans
Mycobacterium	Pleomorphic, spherical or rod-shaped, frequently branching, no gram stain, aerobic; commonly form yellow pigments; include <i>Mycobacterium tuberculosis</i> , 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 (<i>myco-</i> means 'fungus')
Nitrogen-fixing	Rod-shaped, gram-negative, aerobic; convert atmospheric nitrogen gas to ammonium in soil; include <i>Azotobacter</i> , a common genus
Propionic acid	Rod-shaped, pleomorphic, gram-positive, anaerobic; ferment lactic acid; fermentation produces holes in Swiss cheese from the production of carbon dioxide
Pseudomonad	Rod-shaped (straight or curved) with polar flagella, gram-negative, aerobic; can use up to 100 different compounds for carbon and energy
Rickettsia	Spherical or rod-shaped, gram-negative, aerobic; cause Rocky Mountain spotted fever and typhus; closely related to <i>Agrobacterium</i> , a common gall-causing plant bacterium
Sheathed	Filamentous, gram-negative, aerobic; 'swarmer' (colonizing) cells form and break out of a sheath; sometimes coated with metals from environment

Spirillum	Spiral-shaped, gram-negative, aerobic; include <i>Bdellovibrio</i> , 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 <i>Treponemapallidum</i> , cause of syphilis
Sulfate- and Sulfur-reducing	Commonly rod-shaped, mostly gram-negative, anaerobic; include <i>Desulfovibrio</i> , 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
Vibrio	Rod- or comma-shaped, gram-negative, aerobic; commonly with a single flagellum; include <i>Vibrio cholerae</i> , cause of cholera, and luminescent forms symbiotic with deep-water fishes and squids

Gram⁺

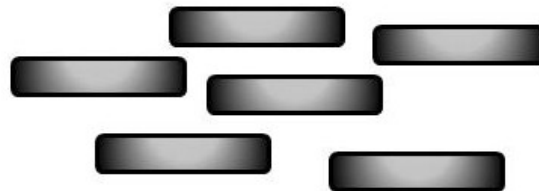


Lactobacillus acidophilus



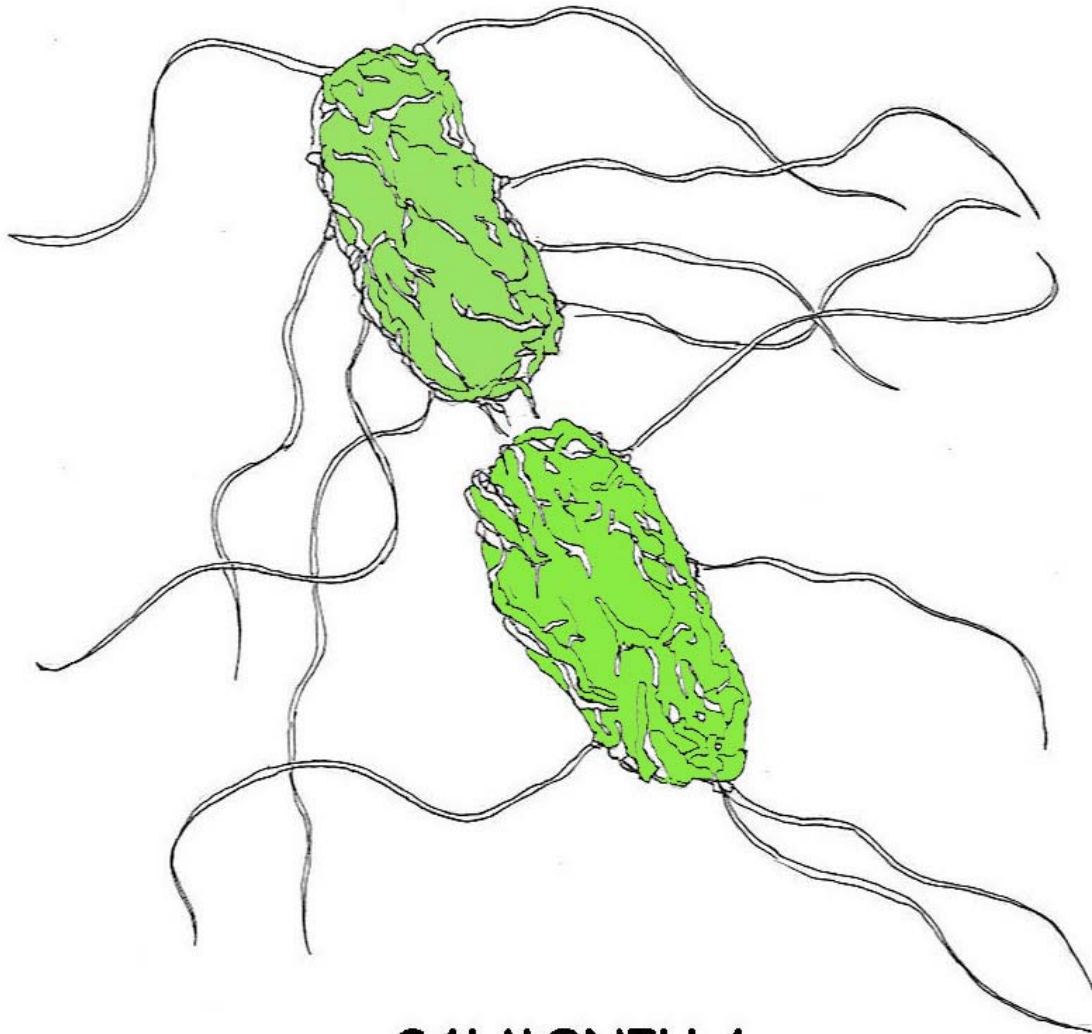
Streptococcus thermophilus

Gram⁻



Escherichia coli

Salmonella



SALMONELLA

Salmonella is a Gram-negative bacterium. It is found in many turtles and other reptiles. In clinical laboratories, it is usually isolated on MacConkey agar, XLD agar, XLT agar, DCA agar, or Önöz agar. Because they cause intestinal infections and are greatly outnumbered by the bacteria normally found in the healthy bowel, primary isolation requires the use of a selective medium, so use of a relatively non-selective medium such as CLED agar is not often practiced. Numbers of salmonella may be so low in clinical samples that stools are routinely also subjected to "enrichment culture", where a small volume of stool is incubated in a selective broth medium, such as selenite broth or Rappaport Vassiliadis soya peptone broth, overnight. These media are inhibitory to the growth of the microbes normally found in the healthy human bowel, while allowing salmonellae to become enriched in numbers. Salmonellae may then be recovered by inoculating the enrichment broth on one or more of the primary selective media. On blood agar, they form moist colonies about 2 to 3 mm in diameter.

When the cells are grown for a prolonged time at a range of 25—28°C, some strains produce a biofilm, which is a matrix of complex carbohydrates, cellulose and proteins. The ability to produce biofilm (a.k.a. "rugose", "lacy", or "wrinkled") can be an indicator of dimorphism, which is the ability of a single genome to produce multiple phenotypes in response to environmental conditions. Salmonellae usually do not ferment lactose; most of them produce hydrogen sulfide which, in media containing ferric ammonium citrate, reacts to form a black spot in the centre of the creamy colonies.

Classification

Salmonella taxonomy is complicated. As of December 7, 2005, there are two species within the genus: *S. bongori* (previously subspecies V) and *S. enterica* (formerly called *S. choleraesuis*), which is divided into six subspecies:

- * I—enterica
- * II—salamae
- * IIIa—arizonae
- * IIIb—diarizonae
- * IV—houtenae
- * V—obsolete (now designated *S. bongori*)
- * VI—indica

There are also numerous (over 2500) serovars within both species, which are found in a disparate variety of environments and which are associated with many different diseases. The vast majority of human isolates (>99.5%) are subspecies *S. enterica*. For the sake of simplicity, the CDC recommends that *Salmonella* species be referred to only by their genus and serovar, e.g.

Salmonella Typhi instead of the more technically correct designation, *Salmonella enterica* subspecies *enterica* serovar Typhi.



Escherichia Coli Section

Fecal Coliform Bacteria

Fecal coliform bacteria are microscopic organisms that live in the intestines of warm-blooded animals. They also live in the waste material, or feces, excreted from the intestinal tract. When fecal coliform bacteria are present in high numbers in a water sample, it means that the water has received fecal matter from one source or another. Although not necessarily agents of disease, fecal coliform bacteria may indicate the presence of disease-carrying organisms, which live in the same environment as the fecal coliform bacteria.

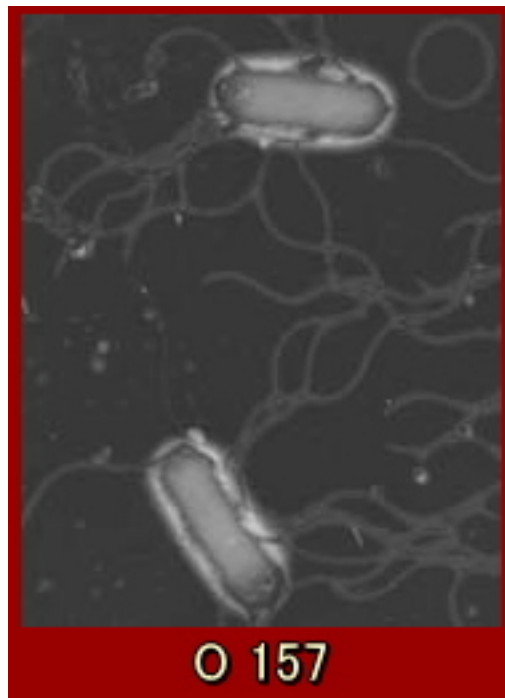
Reasons for Natural Variation

Unlike the other conventional water quality parameters, fecal coliform bacteria are living organisms. They do not simply mix with the water and float straight downstream. Instead they multiply quickly when conditions are favorable for growth, or die in large numbers when conditions are not. Because bacterial concentrations are dependent on specific conditions for growth, and these conditions change quickly, fecal coliform bacteria counts are not easy to predict. For example, although winter rains may wash more fecal matter from urban areas into a stream, cool water temperatures may cause a major die-off. Exposure to sunlight (with its ultraviolet disinfection properties) may have the same effect, even in the warmer water of summertime.

Expected Impact of Pollution

The primary sources of fecal coliform bacteria to fresh water are wastewater treatment plant discharges, failing septic systems, and animal waste. Bacteria levels do not necessarily decrease as a watershed develops from rural to urban. Instead, urbanization usually generates new sources of bacteria. Farm animal manure and septic systems are replaced by domestic pets and leaking sanitary sewers. In fact, stormwater runoff in urbanized areas has been found to be surprisingly high in fecal coliform bacteria concentrations.

The presence of old, disintegrating storm and sanitary sewers, misplaced sewer pipes, and good breeding conditions are common explanations for the high levels measured.



Coliform Standards (in colonies/100ml)

Drinking water.....	1FC
Total body contact (swimming).....	200FC
Partial body contact (boating).....	1000FC
Threatened sewage effluent	not to exceed 200 FC

*Total coliform (TC) includes bacteria from cold-blooded animals and various soil organisms. According to recent literature, total coliform counts are normally about 10 times higher than fecal coliform (FC) counts.

Indicator Connection Varies

General coliforms, E. Coli, and Enterococcus bacteria are the "indicator" organisms generally measured to assess microbiological quality of water. However, these aren't generally what get people sick. Other bacteria, viruses, and parasites are what we are actually worried about.

Because it is so much more expensive and tedious to do so, actual pathogens are virtually never tested for. Over the course of a professional lifetime pouring over indicator tests, in a context where all standards are based on indicators, water workers tend to forget that the indicators are not the things we actually care about.

What are these indicators? More information in the Laboratory section.

- **General coliforms** indicate that the water has come in contact with plant or animal life. General coliforms are universally present, including in pristine spring water. They are of little concern at low levels, except to indicate the effectiveness of disinfection. Chlorinated water and water from perfectly sealed tube wells is the only water I've tested which had zero general coliforms. At very high levels they indicate there is what amounts to a lot of compost in the water, which could easily include pathogens (Ten thousand general coliform bacteria will get you a beach closure, compared to two or four hundred fecal coliforms, or fifty enterococcus).
- **Fecal coliforms**, particularly E. coli, indicate that there are mammal or bird feces in the water.
- **Enterococcus bacteria** also indicate that there are feces from warm blooded animals in the water. Enterococcus are a type of fecal streptococci. They are another valuable indicator for determining the amount of fecal contamination of water.

According to studies conducted by the EPA, enterococci have a greater correlation with swimming-associated gastrointestinal illness in both marine and fresh waters than other bacterial indicator organisms, and are less likely to "die off" in saltwater.

The more closely related the animal, the more likely pathogens excreted with their feces can infect us. Human feces are the biggest concern, because anything which infects one human could infect another. There isn't currently a quantitative method for measuring specifically human fecal bacteria (expensive genetic studies can give a presence/absence result). Ingesting a human stranger's feces via contaminated water supply is a classic means for infections to spread rapidly. The more pathogens an individual carries, the more hazardous their feces. Ingesting feces from someone who is not carrying any pathogens may gross you out, but it can't infect you. Infection rates are around 5% in the US, and approach 100% in areas with poor hygiene and contaminated water supplies. Keep in the back of your mind that **the ratio of indicators to actual pathogens is not fixed**. It will always be different, sometimes very different. Whenever you are trying to form a mental map of reality based on water tests, you should include in the application of your water intuition an adjustment factor for your best guess of the ratio between indicators and actual pathogens.

Membrane Filter Total Coliform Technique

The membrane filter total Coliform technique is used at Medina County for drinking water quality testing. The following is a summary of this test. A sampling procedure sheet is given to all sample takers by Medina County.

The samples are taken in sterile 100 mL containers. These containers, when used for chlorinated water samples, have a sodium thiosulfate pill or solution to dechlorinate the sample.

The sample is placed in cold storage after proper sample taking procedures are followed. (See sample procedures below)

The samples are taken to the laboratory with a chain of custody to assure no tampering of samples can occur.

These samples are logged in at the laboratory.

No longer than 30 hours can lapse between the time of sampling and time of test incubation. (8 hours for heterotrophic, nonpotable 6 hours, others not longer than 24 hours)

All equipment is sterilized by oven and autoclave.

Glassware in oven at $170^{\circ}\text{C} \pm 10^{\circ}\text{C}$ with foil (or other suitable wrap) loosely fitting and secured immediately after sterilization.

Filtration units in autoclave at 121°C for 30 minutes.

Use sterile petri dishes, grid, and pads bought from a reliable company – certified, quality assured - test for satisfactory known positive amounts.

Incubators – $35^{\circ}\text{C} \pm .5^{\circ}\text{C}$ (60% relative humidity)

M-endo medium is prepared and heated to near boiling removed from heat cooled to 45°C pH adjusted to $7.2 \pm .2$ and immediately dispensed 8ml to plates. Keep refrigerated and discard after 2 weeks.



Plates can be stored in a dated box with expiration date and discarded if not used. No denatured alcohol should be used. Everclear or 95% proof alcohol or absolute methyl may be used for sterilizing forceps by flame.

Procedure:

Counters are alcohol wiped.

Bench sheets are filled out.

Samples are removed from refrigeration.

Sterile wrapped utensils are placed on counters.

Filtration units are placed onto sterile membrane filters by aseptic technique using sterile forceps.

Sterile petri dishes are labeled.

The samples closures are clipped.

The sample is shaken 25 times 1 foot in length within 7 seconds.

100 mL is filtered and rinsed with sterile distilled water 3 times.

The membrane filter is aseptically removed from filter holder.

A sterile padded petri dish is used and the membrane filter is rolled onto the pad making sure no air bubbles form.

The sterile labeled lid is placed on the petri dish.

2 blanks and a known is run with each series of samples.

The samples are placed in the $35^{\circ}\text{C} \pm .5^{\circ}\text{C}$ incubator stacked no higher than 3 for 22 – 24 hours (Humidity can be maintained by saturated paper towels placed under containers holding petri dishes.)

After 22- 24 hours view the petri dishes under a 10 –15 power magnification with cool white fluorescent light.

Count all colonies that appear pink to dark red with a metallic surface sheen – the sheen may vary in size from a pin head to complete coverage.

Report as Total Coliform per 100 mL.

If no colonies are present report as <1 coliform/100mL.

Anything greater than 1 is over the limit for drinking water for 2 samples taken 24 hours apart. Further investigation may be necessary – follow Standard Methods accordingly.



Photograph and Credits to Mary McPherson
AranTM Aqua Analytical Laboratory Director.

Escherichia coli EPEC

Two types of pathogenic *Escherichia coli*, enteropathogenic *E. coli* (EPEC) and enterohemorrhagic *E. coli* (EHEC), cause diarrheal disease by disrupting the intestinal environment through the intimate attachment of the bacteria to the intestinal epithelium.

E. coli O157:H7

E. coli O157:H7 (bacterium) found in human feces. Symptoms vary with type caused gastroenteritis.

Escherichia coli O157:H7 is an emerging cause of foodborne illness. An estimated 73,000 cases of infection and 61 deaths occur in the United States each year. Infection often leads to bloody diarrhea, and occasionally to kidney failure. Most illnesses have been associated with eating undercooked, contaminated ground beef. Person-to-person contact in families and child care centers is also an important mode of transmission. Infection can also occur after drinking raw milk and after swimming in or drinking sewage-contaminated water.

Consumers can prevent *E. coli* O157:H7 infection by thoroughly cooking ground beef, avoiding unpasteurized milk, and washing hands carefully. Because the organism lives in the intestines of healthy cattle, preventive measures on cattle farms and during meat processing are being investigated.

What is *Escherichia coli* O157:H7?

E. coli O157:H7 is one of hundreds of strains of the bacterium *Escherichia coli*. Although most strains are harmless and live in the intestines of healthy humans and animals, this strain produces a powerful toxin and can cause severe illness.

E. coli O157:H7 was first recognized as a cause of illness in 1982 during an outbreak of severe bloody diarrhea; the outbreak was traced to contaminated hamburgers. Since then, most infections have come from eating undercooked ground beef.

The combination of letters and numbers in the name of the bacterium refers to the specific markers found on its surface and distinguishes it from other types of *E. coli*.

Currently, there are four recognized classes of enterovirulent *E. coli* (collectively referred to as the EEC group) that cause gastroenteritis in humans. Among these is the enterohemorrhagic (EHEC) strain designated *E. coli* O157:H7. *E. coli* is a normal inhabitant of the intestines of all animals, including humans. When aerobic culture methods are used, *E. coli* is the dominant species found in feces.

Normally *E. coli* serves a useful function in the body by suppressing the growth of harmful bacterial species and by synthesizing appreciable amounts of vitamins. A minority of *E. coli* strains are capable of causing human illness by several different mechanisms. *E. coli* serotype O157:H7 is a rare variety of *E. coli* that produces large quantities of one or more related, potent toxins that cause severe damage to the lining of the intestine. These toxins [verotoxin (VT), shiga-like toxin] are closely related or identical to the toxin produced by *Shigella dysenteriae*.

How does *E. coli* or other fecal coliforms get in the water?

E. coli comes from human and animal wastes. During rainfalls, snow melts, or other types of precipitation, *E. coli* may be washed into creeks, rivers, streams, lakes, or groundwater. When these waters are used as sources of drinking water and the water is not treated or inadequately treated, *E. coli* may end up in drinking water.

How is water treated to protect me from *E. coli*?

The water can be treated using chlorine, ultra-violet light, or ozone, all of which act to kill or inactivate *E. coli*. Systems using surface water sources are required to disinfect to ensure that all bacterial contamination such as *E. coli* is inactivated. Systems using ground water sources are not required to disinfect, although many of them do.

How does the U.S. Environmental Protection Agency regulate *E. coli*?

According to EPA regulations, a system that operates at least 60 days per year, and serves 25 people or more or has 15 or more service connections, is regulated as a public water system under the Safe Drinking Water Act. If a system is not a public water system as defined by EPA regulations, it is not regulated under the Safe Drinking Water Act, although it may be regulated by state or local authorities.

Under the Safe Drinking Water Act, the EPA requires public water systems to monitor for coliform bacteria. Systems analyze first for total coliform, because this test is faster to produce results. Any time that a sample is positive for total coliform, the same sample must be analyzed for either fecal coliform or *E. coli*. Both are indicators of contamination with animal waste or human sewage.

The largest public water systems (serving millions of people) must take at least 480 samples per month. Smaller systems must take at least five samples a month unless the state has conducted a sanitary survey – a survey in which a state inspector examines system components and ensures they will protect public health – at the system within the last five years.

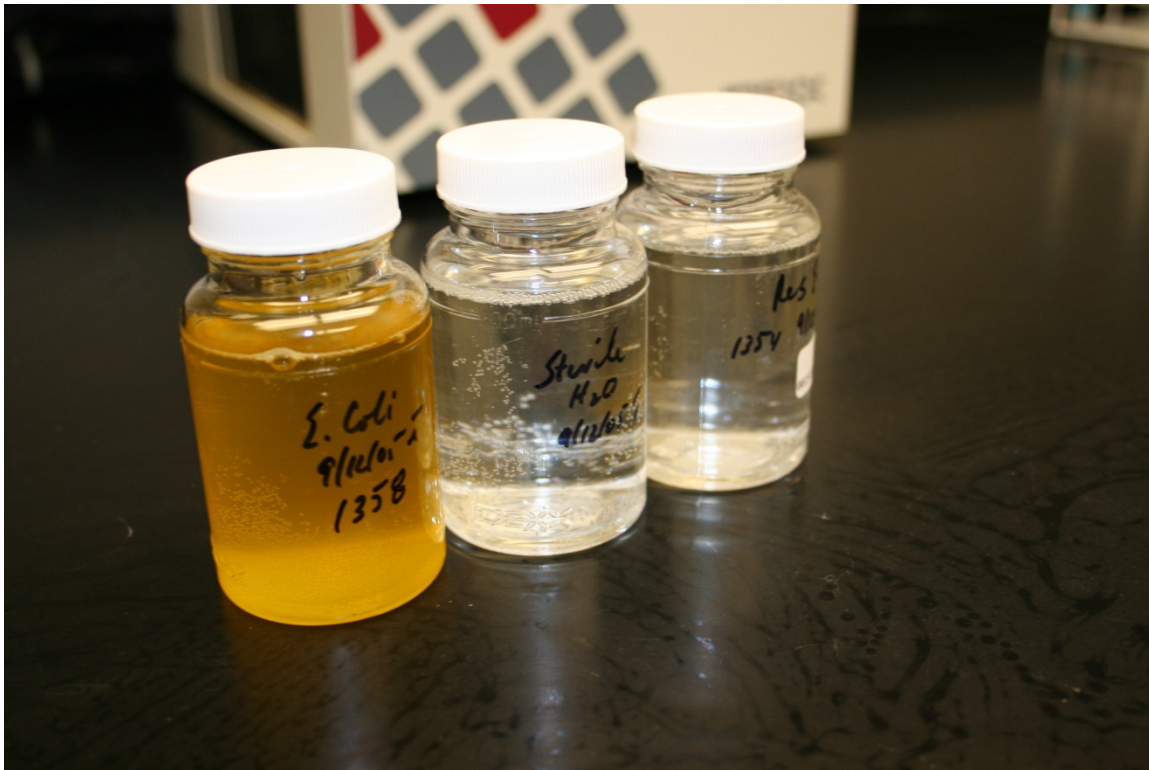
Systems serving 25 to 1,000 people typically take one sample per month. Some states reduce this frequency to quarterly for ground water systems if a recent sanitary survey shows that the system is free of sanitary defects. Some types of systems can qualify for annual monitoring. Systems using surface water, rather than ground water, are required to take extra steps to protect against bacterial contamination because surface water sources are more vulnerable to such contamination. At a minimum, all systems using surface waters must disinfect. Disinfection will kill *E. coli* O157:H7.

What can I do to protect myself from *E. coli* O157:H7 in drinking water?

Approximately 89 percent of Americans are receiving water from community water systems that meet all health-based standards. Your public water system is required to notify you if, for any reason, your drinking water is not safe. If you wish to take extra precautions, you can boil your water for one minute at a rolling boil, longer at higher altitudes. To find out more information about your water, see the Consumer Confidence Report from your local water supplier or contact your local water supplier directly. You can also obtain information about your local water system on the EPA's website at www.epa.gov/safewater/dwinfo.htm.

Positive Tests

If you draw water from a private well, you can contact your state health department to obtain information on how to have your well tested for total coliforms, and *E. coli* contamination. If your well tests positive for *E. coli*, there are several steps that you should take: (1) begin boiling all water intended for consumption, (2) disinfect the well according to procedures recommended by your local health department, and (3) monitor your water quality to make certain that the problem does not recur. If the contamination is a recurring problem, you should investigate the feasibility of drilling a new well or install a point-of-entry disinfection unit, which can use chlorine, ultraviolet light, or ozone.



How is *E. coli* O157:H7 spread?

The organism can be found on a small number of cattle farms and can live in the intestines of healthy cattle. Meat can become contaminated during slaughter, and organisms can be thoroughly mixed into beef when it is ground. Bacteria present on a cow's udders or on equipment may get into raw milk. Eating meat, especially ground beef that has not been cooked sufficiently to kill *E. coli* O157:H7 can cause infection. Contaminated meat looks and smells normal. Although the number of organisms required to cause disease is not known, it is suspected to be very small.

Among other known sources of infection are consumption of sprouts, lettuce, salami, unpasteurized milk and juice, and swimming in or drinking sewage-contaminated water. Bacteria in diarrheal stools of infected persons can be passed from one person to another if hygiene or hand washing habits are inadequate. This is particularly likely among toddlers who are not toilet trained. Family members and playmates of these children are at high risk of becoming infected. Young children typically shed the organism in their feces for a week or two after their illness resolves. Older children rarely carry the organism without symptoms.

What illness does *E. coli* O157:H7 cause?

E. coli O157:H7 infection often causes severe bloody diarrhea and abdominal cramps; sometimes the infection causes non-bloody diarrhea or no symptoms. Usually little or no fever is present, and the illness resolves in 5 to 10 days. Hemorrhagic colitis is the name of the acute disease caused by *E. coli* O157:H7.

In some persons, particularly children under 5 years of age and the elderly, the infection can also cause a complication called hemolytic uremic syndrome, in which the red blood cells are destroyed and the kidneys fail. About 2%-7% of infections lead to this complication. In the United States, hemolytic uremic syndrome is the principal cause of acute kidney failure in children, and most cases of hemolytic uremic syndrome are caused by *E. coli* O157:H7.

**How is *E. coli* O157:H7 infection diagnosed?**

Infection with *E. coli* O157:H7 is diagnosed by detecting the bacterium in the stool. Most laboratories that culture stool do not test for *E. coli* O157:H7, so it is important to request that the stool specimen be tested on sorbitol-MacConkey (SMAC) agar for this organism. All persons who suddenly have diarrhea with blood should get their stool tested for *E. coli* O157:H7.

How is the illness treated?

Most persons recover without antibiotics or other specific treatment in 5-10 days. There is no evidence that antibiotics improve the course of disease, and it is thought that treatment with some antibiotics may precipitate kidney complications. Antidiarrheal agents, such as loperamide (Imodium), should also be avoided. Hemolytic uremic syndrome is a life-threatening condition usually treated in an intensive care unit. Blood transfusions and kidney dialysis are often required. With intensive care, the death rate for hemolytic uremic syndrome is 3%-5%.

Legionnaires' Disease Legionella Section

Introduction Genus: *Legionella* Species: *pneumophila*

The first discovery of bacteria from genus *Legionella* came in 1976 when an outbreak of pneumonia at an American Legion convention led to 29 deaths. The causative agent, what would come to be known as *Legionella pneumophila*, was isolated and given its own genus. The organisms classified in this genus are Gram-negative bacteria that are considered intracellular parasites. The disease has two distinct forms:

- Legionnaires' disease, the more severe form of infection which includes pneumonia, and
- Pontiac fever, a milder illness.

What have been the water sources for Legionnaires' disease?

The major source is water distribution systems of large buildings, including hotels and hospitals. Cooling towers have long been thought to be a major source for *Legionella*, but new data suggest that this is an overemphasized mode of transmission. Other sources include mist machines, humidifiers, whirlpool spas, and hot springs. Air conditioners are not a source for Legionnaires' disease. They were suspected to be the source in the original American Legion outbreak in a Philadelphia hotel, but new data now suggests that the water in the hotel was the actual culprit.

Legionnaire's disease is caused most commonly by the inhalation of small droplets of water or fine aerosol containing *Legionella* bacteria. *Legionella* bacteria are naturally found in environmental water sources such as rivers, lakes and ponds and may colonize man-made water systems that include air conditioning systems, humidifiers, cooling tower waters, hot water systems, spas and pools.

How do people contract *Legionella*?

The most popular theory is that the organism is aerosolized in water and people inhale the droplets containing *Legionella*. However, new evidence suggests that another way of contracting *Legionella* is more common. "Aspiration" is the most common way that bacteria enter into the lungs to cause pneumonia. Aspiration means choking such that secretions in the mouth get past the choking reflexes and instead of going into the esophagus and stomach, mistakenly, enter the lung. The protective mechanisms to prevent aspiration is defective in patients who smoke or have lung disease. Aspiration now appears to be the most common mode of transmission.

Legionella may multiply to high numbers in cooling towers, evaporative condensers, air washers, humidifiers, hot water heaters, spas, fountains, and plumbing fixtures. Within one month, *Legionella* can multiply, in warm water-containing systems, from less than 10 per milliliter to over 1,000 per milliliter of water. Once high numbers of *Legionella* have been found, a relatively simple procedure for disinfecting water systems with chlorine and detergent is available. This procedure is not part of a routine maintenance program because equipment may become corroded.



Property owners have been sued for the spread of Legionella, resulting in expensive settlements. Regular monitoring with a battery of DFA monoclonal antibodies for several serogroups and species of Legionella morphologically intact bacteria provides a means for exercising 'reasonable care' to deter potential litigation.

Currently, there are no United States government regulations concerning permissible numbers of legionella in water systems and there are no federal or state certification programs for laboratories that perform legionella testing of environmental samples.

Epifluorescence Microscopy DFA Method

The epifluorescence microscopy DFA method that most labs use was published in the British Journal, Water Research 19:839-848, 1985 "Disinfection of circulating water systems by ultraviolet light and halogenation", R. Gilpin, et al. so we can count viable-but-nonculturable (VBNC) legionella.

Most labs will provide a quantitative epifluorescence microscopic analysis of your cooling tower and potable water samples for 14 serogroups of Legionella pneumophila and 15 other Legionella species (listed below).

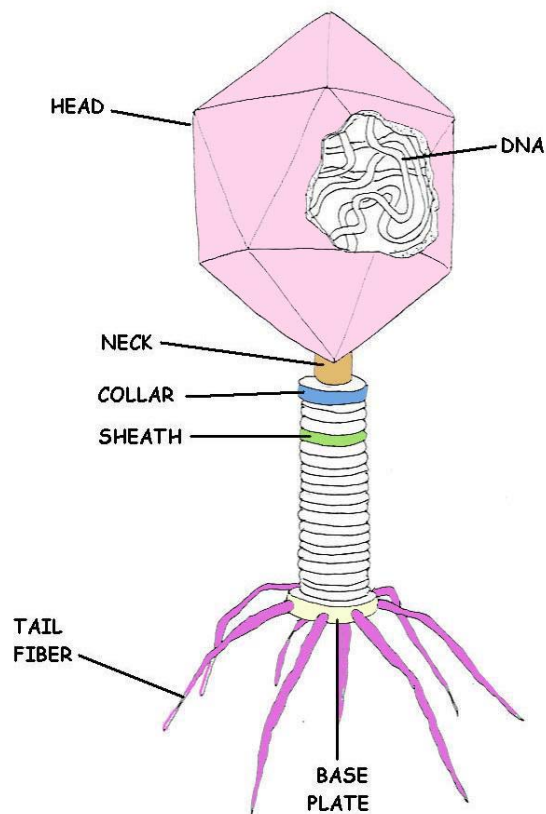
<i>Legionella anisa</i>	<i>Legionella bozemanii</i> sg 1 & 2
<i>Legionella dumoffi</i>	<i>Legionella feeleeii</i> sg 1 & 2
<i>Legionella gormanii</i>	<i>Legionella hackeliae</i> sg 1 & 2
<i>Legionella jordanis</i>	<i>Legionella longbeachae</i> sg 1 & 2
<i>Legionella maceachernii</i>	<i>Legionella micdadei</i>
<i>Legionella oakridgensis</i>	<i>Legionella parisiensis</i>
<i>Legionella pneumophila</i> sg 1-14	<i>Legionella sainthelensi</i>
<i>Legionella santicrucis</i>	<i>Legionella wadsworthii</i>

Heterotrophic bacterial CFU are often inversely proportional to numbers of Legionella in cooling tower samples, in our experience. Routine biocide treatments will not eradicate Legionella bacteria in the environment, only in laboratory studies.

Culture methods are good during outbreaks for bio-typing; but culture methods lack sensitivity for routine, quantitative monitoring. Many factors will inhibit growth or identification of legionella on BCYE with or without antimicrobial agents, heat or acid treatment.

Culture methods will not identify non-culturable legionella that can still cause outbreaks (non-culturable, viable legionella have been reported in several peer-reviewed journals). Only DFA tests performed by trained laboratory personnel can identify these legionella. Direct fluorescent antibody (DFA) tests using a battery of monoclonal antibodies provide more useful routine monitoring information than culture methods. Legionella species of bacteria cause Legionnaire's disease. They are gram negative (but stain poorly), strictly aerobic rods.

The U.S. Environmental Protection Agency and the U.S. Occupational Safety and Health Administration recommend routine maintenance of water-containing equipment. Most State health departments recommend monthly testing for Legionella as part of a routine maintenance program.



BACTERIOPHAGE

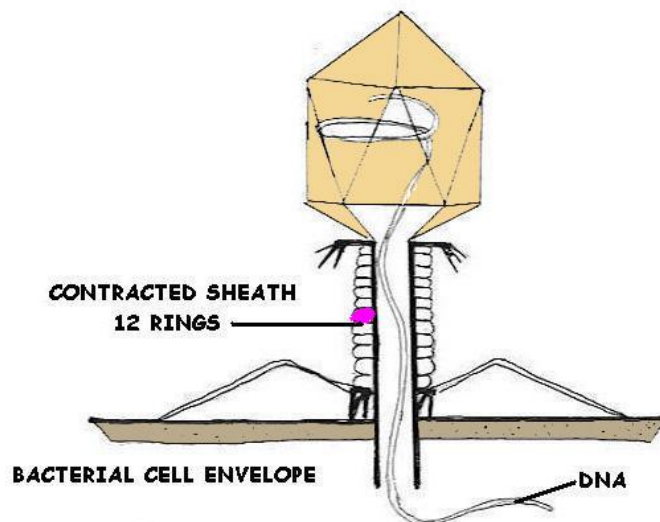
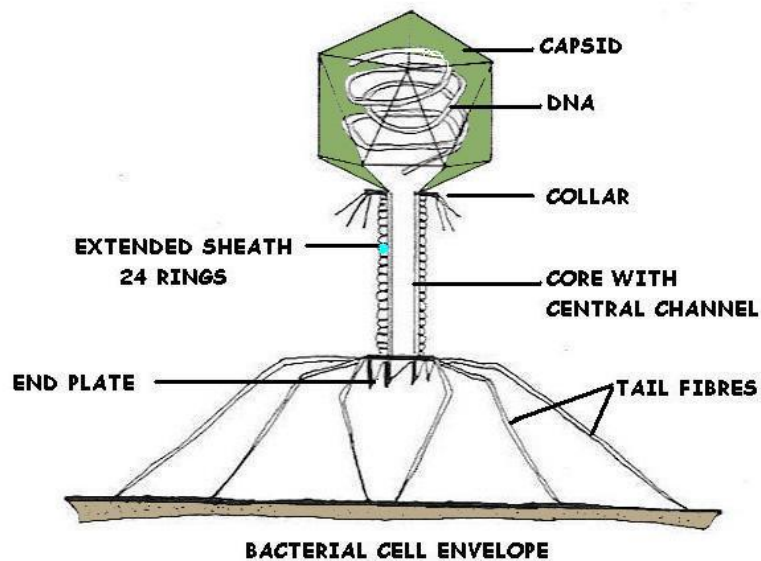
Bacteriophage

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.

Phages are estimated to be the most widely distributed and diverse entities in the biosphere. Phages are ubiquitous and can be found in all reservoirs populated by bacterial hosts, such as soil or the intestine of animals. One of the densest natural sources for phages and other viruses is sea water, where up to 9×10^8 virions per milliliter have been found in microbial mats at the surface, and up to 70% of marine bacteria may be infected by phages.

VIRUS CAPSID (BACTERIOPHAGES)

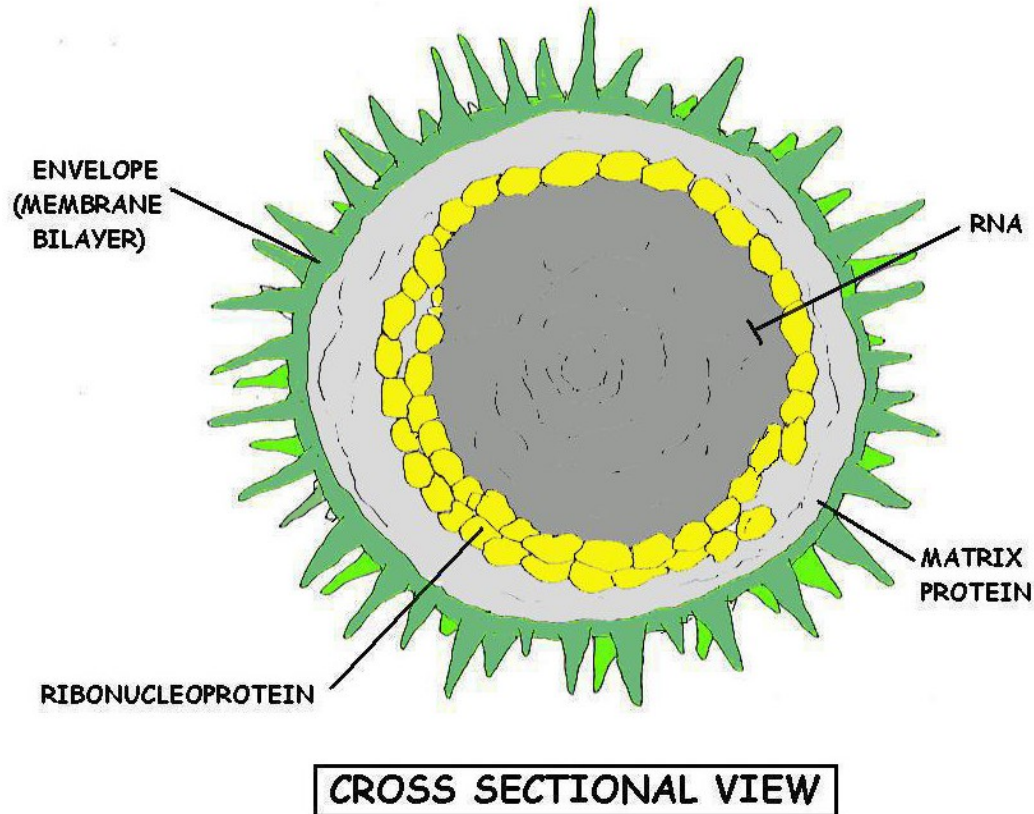


Release of Virions

Phages may be released via cell lysis or by host cell secretion. In the case of the T4 phage, in just over twenty minutes after injection upwards of three hundred phages will be released via lysis within a certain timescale. This is achieved by an enzyme called endolysin which attacks and breaks down the peptidoglycan. In contrast, "lysogenic" phages do not kill the host but rather become long-term parasites and make the host cell continually secrete more new virus particles. The new virions bud off the plasma membrane, taking a portion of it with them to become enveloped viruses possessing a viral envelope. All released virions are capable of infecting a new bacterium.

Viruses

Viruses are acellular microorganisms. They are made up of only genetic material and a protein coat. Viruses depend on the energy and metabolic machinery of the host cell to reproduce. A virus is an infectious agent found in virtually all life forms, including humans, animals, plants, fungi, and bacteria. Viruses consist of genetic material—either deoxyribonucleic acid (DNA) or ribonucleic acid (RNA)—surrounded by a protective coating of protein, called a capsid, with or without an outer lipid envelope. Viruses are between 20 and 100 times smaller than bacteria and hence are too small to be seen by light microscopy.



Viruses vary in size from the largest poxviruses of about 450 nanometers (about 0.000014 in) in length to the smallest polioviruses of about 30 nanometers (about 0.000001 in). Viruses are not considered free-living, since they cannot reproduce outside of a living cell; they have evolved to transmit their genetic information from one cell to another for the purpose of replication. Viruses often damage or kill the cells that they infect, causing disease in infected organisms. A few viruses stimulate cells to grow uncontrollably and produce cancers. Although many infectious diseases, such as the common cold, are caused by viruses, there are no cures for these illnesses. The difficulty in developing antiviral therapies stems from the large number of variant viruses that can cause the same disease, as well as the inability of drugs to disable a virus without disabling healthy cells. However, the development of antiviral agents is a major focus of current research, and the study of viruses has led to many discoveries important to human health.

Virions

Individual viruses, or virus particles, also called virions, contain genetic material, or genomes, in one of several forms. Unlike cellular organisms, in which the genes always are made up of DNA, viral genes may consist of either DNA or RNA. Like cell DNA, almost all viral DNA is double-stranded, and it can have either a circular or a linear arrangement. Almost all viral RNA is single-stranded; it is usually linear, and it may be either segmented (with different genes on different RNA molecules) or non-segmented (with all genes on a single piece of RNA).

Capsids

The viral protective shell, or capsid, can be either helical (spiral-shaped) or icosahedral (having 20 triangular sides). Capsids are composed of repeating units of one or a few different proteins. These units are called protomers or capsomers. The proteins that make up the virus particle are called structural proteins. Viruses also carry genes for making proteins that are never incorporated into the virus particle and are found only in infected cells. These viral proteins are called nonstructural proteins; they include factors required for the replication of the viral genome and the production of the virus particle.

Capsids and the genetic material (DNA or RNA) they contain are together referred to as nucleocapsids. Some virus particles consist only of nucleocapsids, while others contain additional structures.

Some icosahedral and helical animal viruses are enclosed in a lipid envelope acquired when the virus buds through host-cell membranes. Inserted into this envelope are glycoproteins that the viral genome directs the cell to make; these molecules bind virus particles to susceptible host cells.

Bacteriophages

The most elaborate viruses are the bacteriophages, which use bacteria as their hosts. Some bacteriophages resemble an insect with an icosahedral head attached to a tubular sheath. From the base of the sheath extend several long tail fibers that help the virus attach to the bacterium and inject its DNA to be replicated, direct capsid production, and virus particle assembly inside the cell.

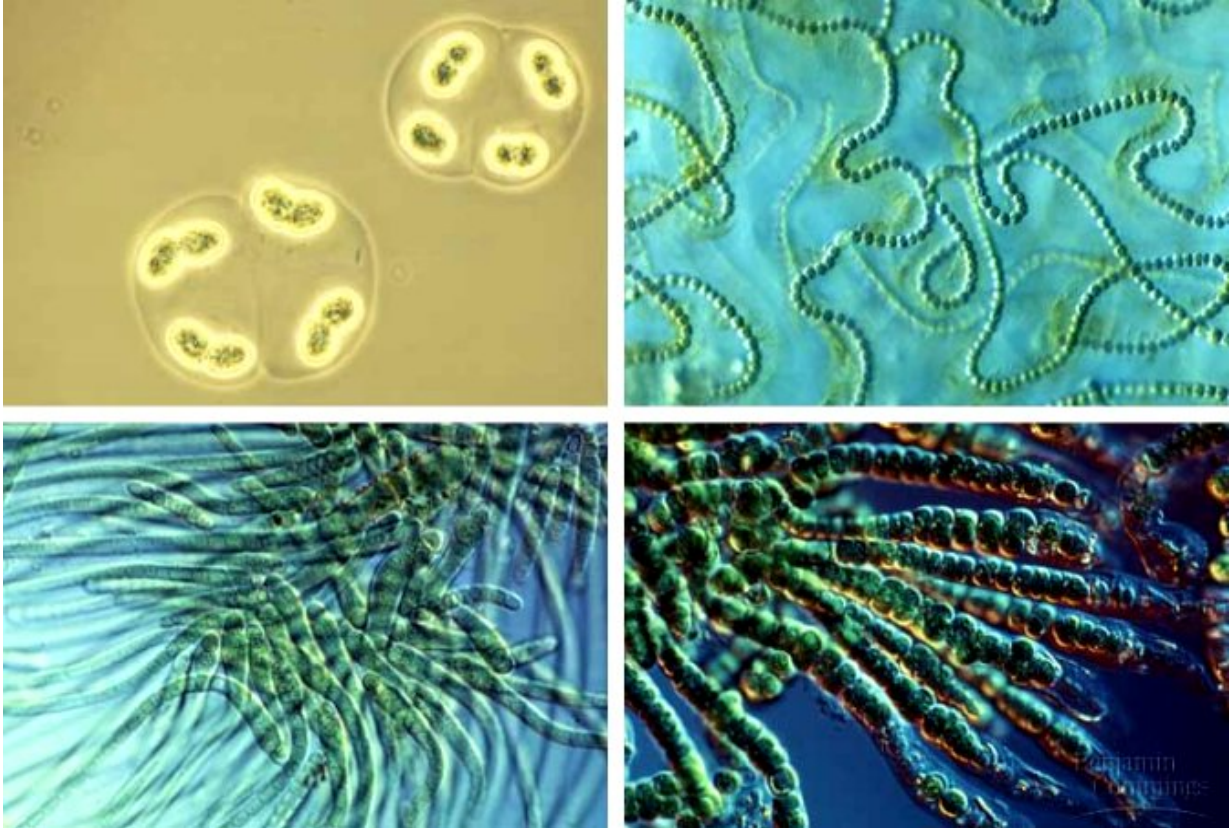
Viroids and Prions

Viroids and prions are smaller than viruses, but they are similarly associated with disease. Viroids are plant pathogens that consist only of a circular, independently replicating RNA molecule. The single-stranded RNA circle collapses on itself to form a rod-like structure. The only known mammalian pathogen that resembles plant viroids is the deltavirus (hepatitis D), which requires hepatitis B virus proteins to package its RNA into virus particles. Co-infection with hepatitis B and D can produce more severe disease than can infection with hepatitis B alone. Prions are mutated forms of a normal protein found on the surface of certain animal cells.

Virus Classification

Viruses are classified according to their type of genetic material, their strategy of replication, and their structure. The International Committee on Nomenclature of Viruses (ICNV), established in 1966, devised a scheme to group viruses into families, subfamilies, genera, and species. The ICNV report published in 1995 assigned more than 4000 viruses into 71 virus families. Hundreds of other viruses remain unclassified because of the lack of sufficient information.

Cyanobacteria



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.

Cyanobacteria include unicellular and colonial species. Colonies may form filaments, sheets or even hollow balls. Some filamentous colonies show the ability to differentiate into several different cell types: vegetative cells, the normal, photosynthetic cells that are formed under favorable growing conditions; akinetes, the climate-resistant spores that may form when environmental conditions become harsh; and thick-walled heterocysts, which contain the enzyme nitrogenase, vital for nitrogen fixation. Heterocysts may also form under the appropriate environmental conditions (anoxic) wherever nitrogen is necessary. Heterocyst-forming species are specialized for nitrogen fixation and are able to fix nitrogen gas, which cannot be used by plants, into ammonia (NH_3), nitrites (NO_2) or nitrates (NO_3), which can be absorbed by plants and converted to protein and nucleic acids.

The rice paddies of Asia, which produce about 75% of the world's rice, could not do so were it not for healthy populations of nitrogen-fixing cyanobacteria in the rice paddy fertilizer too.

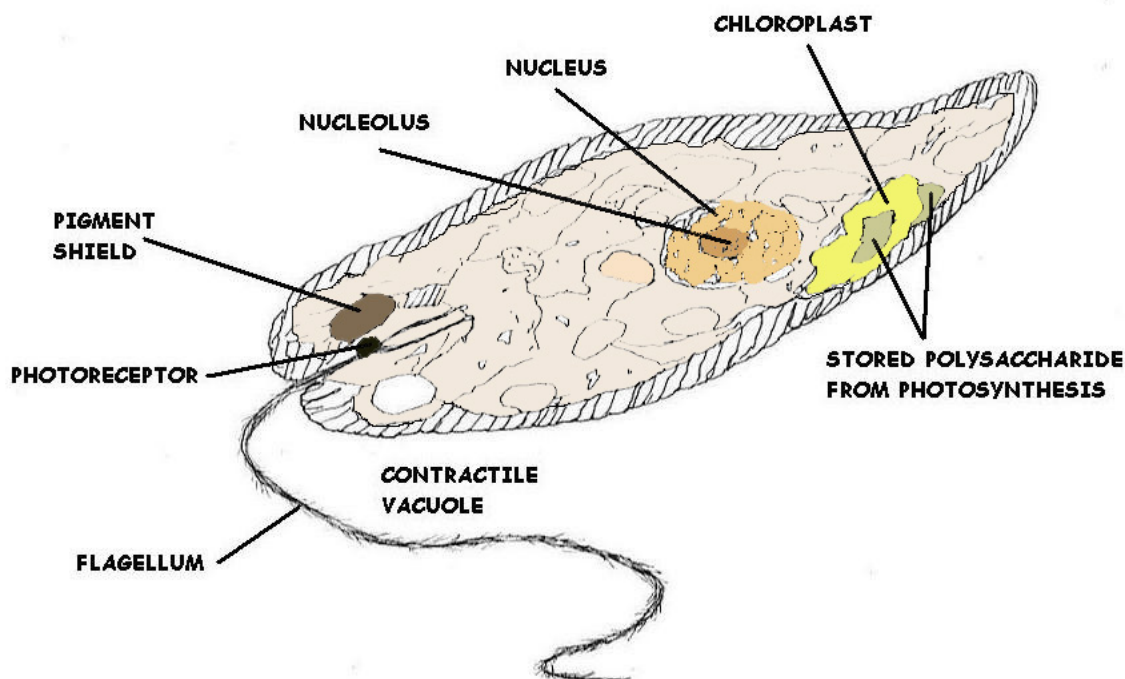
Many cyanobacteria also form motile filaments, called hormogonia, that travel away from the main biomass to bud and form new colonies elsewhere. The cells in a hormogonium are often thinner than in the vegetative state, and the cells on either end of the motile chain may be tapered. In order to break away from the parent colony, a hormogonium often must tear apart a weaker cell in a filament, called a necridium.

Each individual cell of a cyanobacterium typically has a thick, gelatinous cell wall. They differ from other gram-negative bacteria in that the quorum sensing molecules autoinducer-2[4] and acyl-homoserine lactones are absent. They lack flagella, but hormogonia and some unicellular species may move about by gliding along surfaces. In water columns some cyanobacteria float by forming gas vesicles, like in archaea.



TAKING A SAMPLE FROM A STREAM

EUGLENA



Euglena

Euglenas 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. In order for *Euglena gracilis* to make more *Euglena gracilis* it will complete a process called mitosis. That means it can split itself in half and become two *Euglena gracilis*. It can only do this if it is well-fed and if the temperature is right. *Euglena gracilis* can reproduce better in warm temperatures.

Euglena gracilis, and other euglena, are harmless to people, but they are often signs that water is polluted, since they do well where there is a lot of green algae to eat. Green algae does well where there is a lot of nitrogen (comes from waste) in the water. If you don't clean your swimming pool, leaves and twigs get in the water and turn into waste. Then algae and euglena show up.

KINGDOM: Protist, PHYLUM: Euglenophyta, CLASS: Euglenophyceae, ORDER: Euglenales, FAMILY: Euglenidae, GENUS: *Euglena*, SPECIES: *Euglena gracilis*

Peptidoglycan

Peptidoglycan, also known as murein, is a polymer consisting of sugars and amino acids that forms a mesh-like layer outside the plasma membrane of eubacteria. The sugar component consists of alternating residues of β -(1,4) linked N-acetylglucosamine and N-acetylmuramic acid residues. Attached to the N-acetylmuramic acid is a peptide chain of three to five amino acids. The peptide chain can be cross-linked to the peptide chain of another strand forming the 3D mesh-like layer.



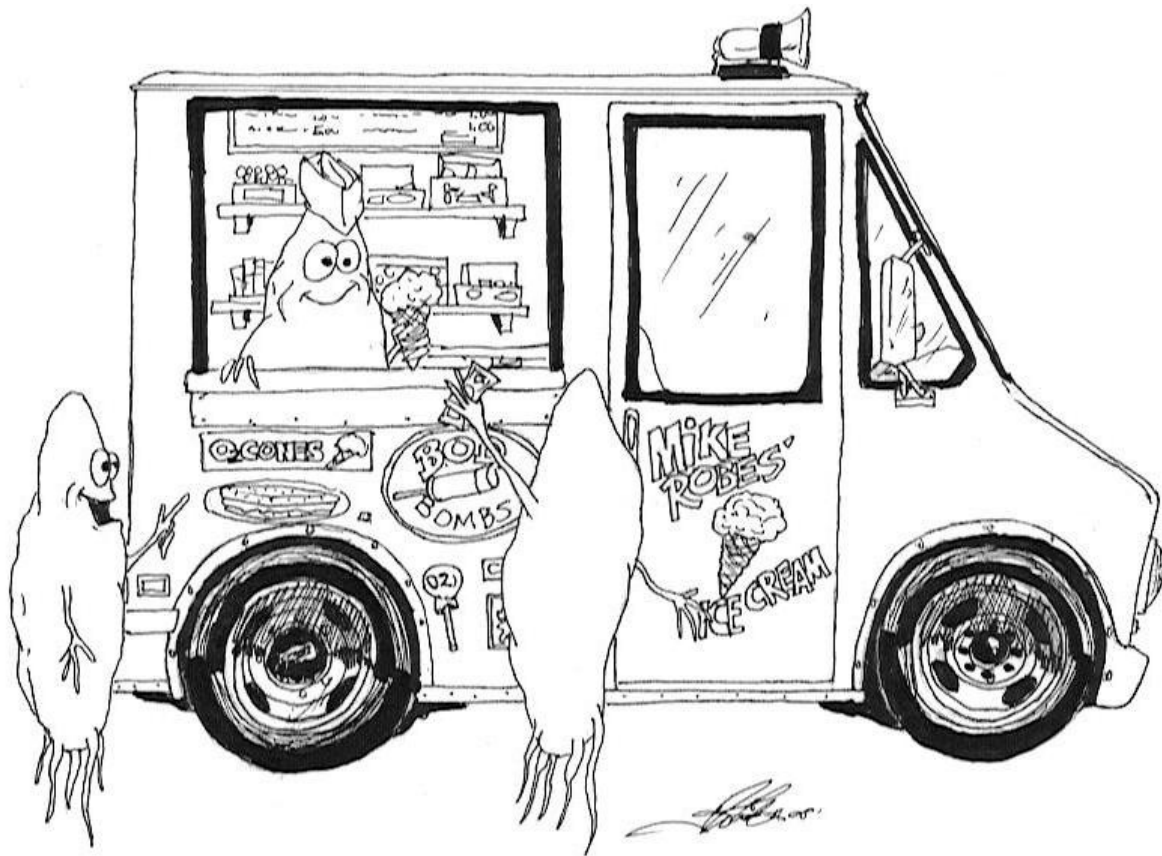
Hepatitis



HEPATITIS VIRUS

There are five types of hepatitis -- A through E -- all of which cause inflammation of the liver. Type D affects only those who also have hepatitis B, and hepatitis E is extremely rare in the United States.

- Type A hepatitis is contracted through anal-oral contact, by coming in contact with the feces of someone with hepatitis A, or by eating or drinking hepatitis A contaminated food or water.
- Type B hepatitis can be contracted from infected blood, seminal fluid, vaginal secretions, or contaminated drug needles, including tattoo or body-piercing equipment. It can also be spread from a mother to her newborn.
- Type C hepatitis is not easily spread through sex. You're more likely to get it through contact with infected blood, contaminated razors, needles, tattoo and body-piercing equipment, or manicure or pedicure tools that haven't been properly sanitized, and a mother can pass it to her baby during delivery.
- Type D hepatitis can be passed through contact with infected blood, contaminated needles, or by sexual contact with an HIV-infected person.
- Type E hepatitis is most likely to be transmitted in feces, through oral contact, or in water that's been contaminated.



Chemical Equipment Photograph Summaries



Lime slaker used for coagulation and water softening. The photograph on right is the hopper and conveyor for the lime.



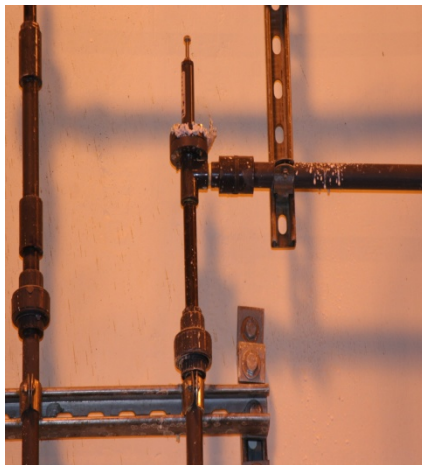
This operator is preparing to take the lime feeder off-line. It is very important to remove all residual chemical so that it doesn't harden in the equipment.



This photograph shows the containers of Lime slurry that was removed from the equipment after being placed out of service. The Lime had already hardened.



High rate feed pumps are used at this particular plant for Alum. The photograph on the right shows 3 positive displacement pumps in parallel operation.



These photographs show an Alum leak. When exposed to air, this chemical becomes crystallized.



Some water treatment plants use Powder Activated Carbon (**PAC**) for taste and odor. As you can see in these photographs it can be very messy. Proper storage procedures must be implemented.



This water operator is checking to see if the Rota-dip is in operation. This is used to feed liquid chemicals in solution such as polymers.



These photographs show chemical lines using schedule 80 PVC. The pipes are exposed to sunlight and this causes the pipes to break especially when the protective paint is worn off.



The above photographs shows polymer chemical feed pumps used in sludge thickening. The photograph on the right is a bulk container for the polymer. The Hazard Communication Standard (29 CFR 1910.1200) specifically requires every hazardous chemical container to have a label. Labels are part of the company's Hazard Communication Program, which gives employees the Right to Know about the chemical hazards they face on the job.



Most water treatment plants use bulk containment for chemicals storage. The plants are required to have containment walls to hold any spilled chemicals from the tanks.



These photographs above show containers that hold a mixture of rain water and chemicals. Not all chemicals are allowed to be discharged into the sewers so they have to be sent out as a hazardous waste.



This photograph shows a delivery of Sulfuric Acid. The delivery driver is wearing only work gloves. He is clearly in violation of the proper PPE. The Hazard Communication Standard requires employees to understand chemical hazards, labels, and MSDSs and to use them on the job. Before starting jobs involving possible exposure to hazardous substances, employees must read MSDSs to know what they're working with and procedures for safe handling.



This is a rectangular water treatment sedimentation basin. The holes in the wall are used to increase the contact time so that the particles can floc and settle out properly.



The **MSDS** is every worker's guide to safe handling of hazardous substances. An individual chemical's hazards determine exactly what information the MSDS contains. However, it always contains the information needed to avoid accidents and illness when handling that substance. Stress to employees the importance of reading the MSDS before starting a job.

Math Conversion Factors and Practical Exercise

1 PSI = 2.31 Feet of Water
 1 Foot of Water = .433 PSI
 1.13 Feet of Water = 1 Inch of Mercury
 454 Grams = 1 Pound
 2.54 CM = Inch
 1 Gallon of Water = 8.34 Pounds
 1 mg/L = 1 PPM
 17.1 mg/L = 1 Grain/Gallon
 1% = 10,000 mg/L
 694 Gallons per Minute = MGD
 1.55 Cubic Feet per Second = 1 MGD
 60 Seconds = 1 Minute
 1440 Minutes = 1 Day
 .746 kW = 1 Horsepower

LENGTH

12 Inches = 1 Foot
 3 Feet = 1 Yard
 5280 Feet = 1 Mile

AREA

144 Square Inches = 1 Square Foot
 43,560 Square Feet = 1 Acre

VOLUME

1000 Milliliters = 1 Liter
 3.785 Liters = 1 Gallon
 231 Cubic Inches = 1 Gallon
 7.48 Gallons = 1 Cubic Foot of water
 62.38 Pounds = 1 Cubic Foot of water

Dimensions

SQUARE: Area (sq.ft.) = Length X Width
 Volume (cu.ft.) = Length (ft) X Width (ft) X Height (ft)

CIRCLE: Area (sq.ft.) = 3.14 X Radius (ft) X Radius (ft)

CYLINDER: Volume (Cu. ft) = 3.14 X Radius (ft) X Radius (ft) X Depth (ft)

PIPE VOLUME: .785 X Diameter ² X Length = ? To obtain gallons multiply by 7.48

SPHERE: $\frac{(3.14) (\text{Diameter})^3}{(6)}$ Circumference = 3.14 X Diameter

General Conversions

Flowrate

Multiply	→	to get
to get	←	Divide
cc/min	1	mL/min
cfm (ft ³ /min)	28.31	L/min
cfm (ft ³ /min)	1.699	m ³ /hr
cfh (ft ³ /hr)	472	mL/min
cfh (ft ³ /hr)	0.125	GPM
GPH	63.1	mL/min
GPH	0.134	cfh
GPM	0.227	m ³ /hr
GPM	3.785	L/min
oz/min	29.57	mL/min



POUNDS PER DAY = Concentration (mg/L) X Flow (MG) X 8.34

A.K.A. Solids Applied Formula = Flow X Dose X 8.34 *Professor Rusty's Favorite Math Formula*

$$\text{PERCENT EFFICIENCY} = \frac{\text{In} - \text{Out}}{\text{In}} \times 100$$

$$\begin{aligned} \text{TEMPERATURE: } {}^{\circ}\text{F} &= ({}^{\circ}\text{C} \times 9/5) + 32 & 9/5 &= 1.8 \\ {}^{\circ}\text{C} &= ({}^{\circ}\text{F} - 32) \times 5/9 & 5/9 &= .555 \end{aligned}$$

$$\text{CONCENTRATION: Conc. (A) X Volume (A) = Conc. (B) X Volume (B)}$$

$$\text{FLOW RATE (Q): } Q = A \times V \text{ (Quantity = Area X Velocity)}$$

$$\text{FLOW RATE (gpm): Flow Rate (gpm) = } \frac{2.83 (\text{Diameter, in})^2 (\text{Distance, in})}{\text{Height, in}}$$

$$\% \text{ SLOPE} = \frac{\text{Rise (feet)}}{\text{Run (feet)}} \times 100$$

$$\text{ACTUAL LEAKAGE} = \frac{\text{Leak Rate (GPD)}}{\text{Length (mi.) X Diameter (in)}}$$

$$\text{VELOCITY} = \frac{\text{Distance (ft)}}{\text{Time (Sec)}}$$

N = Manning's Coefficient of Roughness

R = Hydraulic Radius (ft.)

S = Slope of Sewer (ft/ft.)

$$\text{HYDRAULIC RADIUS (ft)} = \frac{\text{Cross Sectional Area of Flow (ft)}}{\text{Wetted pipe Perimeter (ft)}}$$

$$\text{WATER HORSEPOWER} = \frac{\text{Flow (gpm)} \times \text{Head (ft)}}{3960}$$

$$\text{BRAKE HORSEPOWER} = \frac{\text{Flow (gpm)} \times \text{Head (ft)}}{3960 \times \text{Pump Efficiency}}$$

$$\text{MOTOR HORSEPOWER} = \frac{\text{Flow (gpm)} \times \text{Head (ft)}}{3960 \times \text{Pump Eff.} \times \text{Motor Eff.}}$$

$$\text{MEAN OR AVERAGE} = \frac{\text{Sum of the Values}}{\text{Number of Values}}$$

$$\text{TOTAL HEAD (ft)} = \text{Suction Lift (ft)} \times \text{Discharge Head (ft)}$$

$$\text{SURFACE LOADING RATE} = \frac{\text{Flow Rate (gpm)}}{(\text{gal/min/sq.ft}) \times \text{Surface Area (sq. ft)}}$$

$$\begin{aligned} \text{MIXTURE} &= \frac{(\text{Volume 1, gal}) (\text{Strength 1, \%}) + (\text{Volume 2, gal}) (\text{Strength 2, \%})}{(\text{Volume 1, gal}) + (\text{Volume 2, gal})} \\ \text{STRENGTH (\%)} & \end{aligned}$$

$$\text{INJURY FREQUENCY RATE} = \frac{(\text{Number of Injuries}) \times 1,000,000}{\text{Number of hours worked per year}}$$

$$\text{DETENTION TIME (hrs)} = \frac{\text{Volume of Basin (gals)} \times 24 \text{ hrs}}{\text{Flow (GPD)}}$$

$$\text{SLOPE} = \frac{\text{Rise (ft)}}{\text{Run (ft)}}$$

$$\text{SLOPE (\%)} = \frac{\text{Rise (ft)} \times 100}{\text{Run (ft)}}$$

POPULATION EQUIVALENT (PE):

- 1 PE = .17 Pounds of BOD per Day
- 1 PE = .20 Pounds of Solids per Day
- 1 PE = 100 Gallons per Day

$$\text{LEAKAGE (GPD/inch)} = \frac{\text{Leakage of Water per Day (GPD)}}{\text{Sewer Diameter (inch)}}$$

$$\text{CHLORINE DEMAND (mg/L)} = \text{Chlorine Dose (mg/L)} - \text{Chlorine Residual (mg/L)}$$

τQ = Allowable time for decrease in pressure from 3.5 PSU to 2.5 PSI

τq = As below

$$\tau Q = (0.022) (d_1^2 L_1) / Q \quad \tau q = \frac{[0.085] [(d_1^2 L_1) / (d_1 L_1)]}{q}$$

Q = 2.0 cfm air loss

θ = .0030 cfm air loss per square foot of internal pipe surface

δ = Pipe diameter (inches)

L = Pipe Length (feet)

$$V = \frac{1.486}{v} R^{2/3} S^{1/2}$$

V = Velocity (ft./sec.)

v = Pipe Roughness

R = Hydraulic Radius (ft)

S = Slope (ft/ft)

$$\text{HYDRAULIC RADIUS (ft)} = \frac{\text{Flow Area (ft. }^2\text{)}}{\text{Wetted Perimeter (ft.)}}$$

$$\text{WIDTH OF TRENCH (ft)} = \text{Base (ft)} + (2 \text{ Sides}) \times \frac{\text{Depth (ft }^2\text{)}}{\text{Slope}}$$



Professor Melissa explaining math formulas.



Water Quality: The 4 broad categories of water quality are: Physical, chemical, biological, radiological. Pathogens are disease causing organisms such as bacteria and viruses. A positive bacteriological sample indicates the presence of bacteriological contamination. Source water monitoring for lead and copper be preformed when a public water system exceeds an action level for lead of copper.

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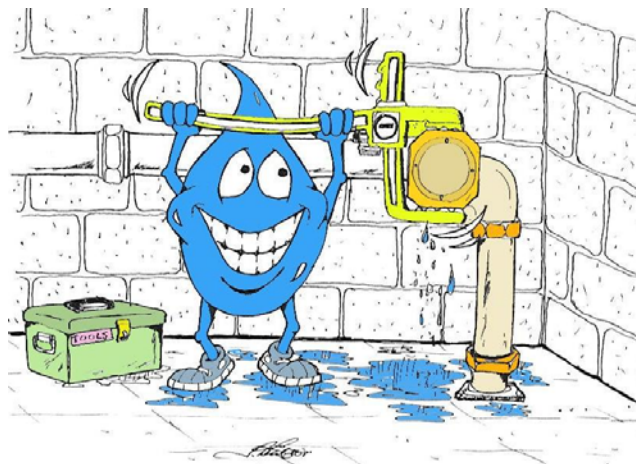
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