Introduction to Water Treatment

Grades 3 & 4

Week 1

Course # 3101

Fleming Training Center
January 28 – February 1, 2013

http://www.tn.gov/environment/fleming/

State of Tennessee

Fleming Training Center

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Your Partner in Clean Water

http://tn.gov/environment/fleming

Water Treatment

Grade 1&2	Grade 3&4 Week 1
Course#2101	Course#3101
Jan 28 - Feb 1, 2013	Jan 28 - Feb 1, 2013

Monday, January 28

8:30	Registration	Amanda Carter
9:00	Overview of Water Treatment	Amanda
10:15	Source Water Protection	Amanda
12:00	Lunch	
1:00	Math Review	Amanda

Tuesday, January 29

8:30	Preliminary Treatment	Amanda
9:30	Coagulation / Flocculation	Amanda
12:00	Lunch	
1:00	Sedimentation	Amanda
2:15	Plant Safety	Amanda

Wednesday, January 30

8:30	Lab Procedures	Amanda
9:45	Filtration	Amanda
12:00	Lunch	
1:00	Pumps & Maintenance	Amanda
2:00	Tour - to be announced	

Thursday, January 31

8:30	Disinfection / Chlorination	Amanda
10:30	Water Tanks	Amanda
11:30	Lunch	
12:30	Rules and Regs	Amanda

Friday, February 1

8:30	Hydrant Flushing	Amanda
9:15	Taste and Odor	Amanda
10:30	Preventative Maintenance	Amanda
11:45	Lunch	
1:00	First Week Exam	Amanda

State of Tennessee

Fleming Training Center
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Table of Contents

Section 1

Overview

Overview of Water Treatment

Purpose of water treatment – to provide safe drinking water that does not contain objectionable taste, odor or color; to provide adequate quantities of water for domestic, commercial, industrial and fire protection needs.

All water produced by public water systems must be drinking water quality, even though only about 1% of water produced is used for drinking and cooking.

Schematic of conventional water treatment:

- Water is withdrawn from a lake, reservoir or river at the intake
- It is screened to remove debris
- Water then enters the flash mixing tank where coagulants and other chemicals are added
- Then it is divided into the flocculation basin
- After flocculation, the water enters the settling basins where solids are removed
- Filtration then removes particles that are too small to settle by gravity
- The water is disinfected using some form of chlorine
- Other chemicals such as fluoride, phosphate corrosion inhibitors or pH adjustment chemicals may be added
- After a minimum detention time, the water may be pumped to the distribution systems

Other processes may occur, such as pre-oxidation or activated carbon treatment.

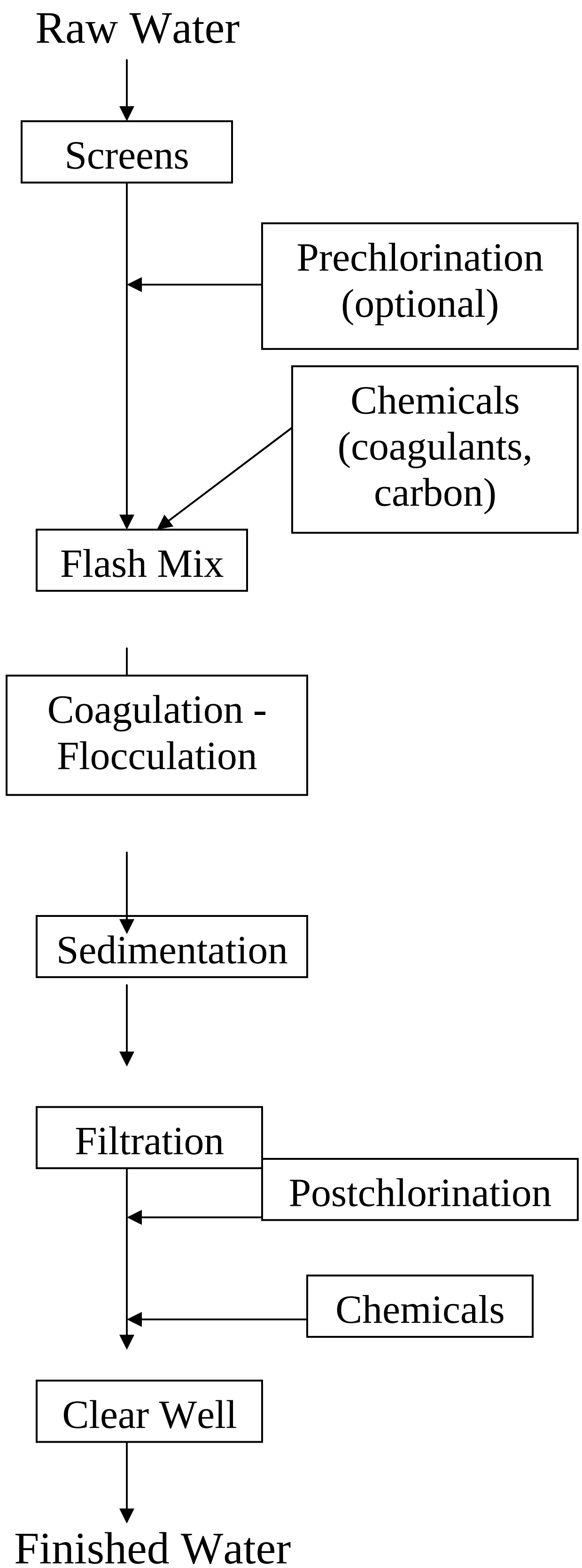
Groundwater treatment is much less involved than surface water treatment. Groundwater has fewer impurities. Aeration may be required to remove dissolved gases and aid in the removal of dissolved minerals. Fluoride is sometimes added, but often the only step is disinfection. Addition of chemicals to reduce corrosion may also be needed.

Various regulations exist to control contaminants in drinking water in order to ensure public safety. Part of an operator's job is to collect samples, test them and report the results to the state, which enforces these regulations. Operators must be able to recognize problems in the treatment process that could result in violations. They should also be familiar with the limits of certain substances in water so they can recognize when lab tests indicate violations.

Common Abbreviations

ASTM – America Society for Testing and Materials
AWWA – America Water Works Association
CCR – consumer confidence report
CWS – community water system
DBP – disinfection byproduct
DO – dissolved oxygen
EBCT – empty bed contact time
GAC – granular activated carbon
HAA – haloacetic acids
HPC – heterotrophic plate count
HTH – high test hypochlorite; calcium hypochlorite
LCR – lead and copper rule
LSI – Langelier saturation index
MCL – maximum contaminant levels
MCLG – maximum contaminant level goal
MF – membrane filter
MGD – million gallons per day
MPN – most probable number
MRDL – maximum residual disinfection level
MSDS – material safety data sheets
MTF - multiple-tube fermentation
NCWS – non-community water system
NOM – natural organic material
NSF – National Sanitation Foundation
NTNCWS – non-transient non-community water system
NTU – nephelometric turbidity units
OSHA – Occupational Safety and Health Act
P-A – presence-absence
PAC – powder activated carbon
PN – public notification
PPE – personal protective equipment
PPM – parts per million; mg/L
PSI – pounds per square inch
PWS – public water system
RPBP – reduced pressure backflow preventor
SCBA – self-contained breathing apparatus
SCD – streaming current detector
SDWA – Safe Drinking Water Act
sMCL – secondary maximum contaminant level
SOC – synthetic organic carbon
SOP – standard operating procedures
TCR – total coliform rule
TDS – total dissolved solids
THM – trihalomethane
TOC – total organic carbon
TWS – transient non-community water system
USEPA – United States Environmental Protection Agency
UV – ultraviolet
VOC – volatile organic chemical

Treatment Process | Purpose



Removes leaves, sticks, fish and other large debris.

Kills most disease-causing organisms and helps control taste and odor causing substances.

Coagulants cause very fine particles to clump together into larger particles.
Carbon can be added in the flash mix to help control taste and odor causing substances.

Mixes chemicals with raw water containing fine particles that will not readily settle or filter out of the water.

Gathers together fine, light particles to form larger particles (floc) to aid the sedimentation and filtration process.

Settles out larger suspended particles.

Filters out remaining suspended particles.

Kills/inactivates disease causing organisms. Provides chlorine residual for distribution system.

Phosphates control corrosion, fluoride helps prevent dental decay.

Provides chlorine contact time for disinfection. Stores water for high demand.

Chemical Formula	Common Name(s)
$Al(OH)_3$	aluminum hydroxide; jellylike floc particles
$Al_2(SO_4)_3 \bullet 7H_2O$	alum; aluminum sulfate
AsO_3	arsenite
AsO_4	arsenate
Br_2	bromine
$CaCl_2$	calcium chloride
$CaCO_3$	calcium carbonate
$Ca(HCO_3)_2$	calcium bicarbonate
CaO	calcium oxide; unslaked lime; quicklime
$Ca(OCl)_2$	calcium hypochlorite; HTH
$Ca(OH)_2$	calcium hydroxide; lime; hydrated lime; slaked lime
$CaSO_4$	calcium sulfate
CH_4	methane
Cl_2	chlorine
ClO_2	chlorine dioxide
CO_2	carbon dioxide
$CuSO_4 \bullet 5H_2O$	copper sulfate; bluestone; copper sulfate pentahydrate
Fe	iron
$FeCl_3$	ferric chloride
$Fe(OH)_3$	ferric hydroxide
Fe_2S_2	iron sulfide
$Fe_2(SO_4)_3$	ferric sulfate
$Fe_2(SO_4)_3 \bullet 7H_2O$	ferrous sulfate
HCl	hydrochloric acid; muriatic acid
H_2O	water
$HOCl$	hypochlorous acid
H_2S	hydrogen sulfide
H_2SiF_6	fluorosilicic acid; hydrofluorosilicic acid; silly acid
H_2SO_4	sulfuric acid
I_2	iodine
$KMnO_4$	potassium permanganate
$MgCl_2$	magnesium chloride
$MgCO_3$	magnesium carbonate
$Mg(HCO_3)_2$	magnesium bicarbonate
$Mg(OH)_2$	magnesium hydroxide
$MgSO_4$	magnesium sulfate
Mn	manganese

Chemical Formula	Common Name(s)
$Na_2Al_2O_4$	sodium aluminate
Na_2CO_3	sodium carbonate; soda ash
NaF	sodium fluoride
$NaHCO_3$	sodium bicarbonate; baking powder
$Na_2O \bullet (SiO_2)_3$	sodium silicate
$NaOCl$	sodium hypochlorite; bleach
$NaOH$	sodium hydroxide; caustic soda
$Na_4P_2O_7$	tetrasodium pyrophosphate
$(NaPO)_{14}Na_2O$	sodium hexametaphosphate; sodium polyphosphate
Na_2SiF_6	sodium fluorosilicate; sodium silicofluoride
NCl_3	trichloramine
NH_2Cl	monochloramine
$NHCl_2$	dichloramine
NO_3	nitrate
O_3	ozone
OCl	hypochlorite
SO_4	sulfate
$Zn_3(PO_4)_2$	zinc orthophosphate

Grade 1 Water Treatment Operator
Need-To-Know Criteria (Subject Areas)

The following list of categories suggests topics of information that are important to know in order to be a successful and proficient Grade 4 Water Treatment Operator. The list may not be all-inclusive, and knowledge of additional topics may be of benefit to the operator.

Category of Information: Processes

Pre-Treatment
- Screens (Wells; Intake)

Aeration
- Slat tray

Disinfection
- Gas Chlorinators
- Hypochlorinators
- Chlorine Dioxide
- Mixed Oxidants
- Ultra-violet

Fluoridation
- Fluorosilicic Acid
- Sodium fluoride
- Sodium Fluorosilicate

Corrosion Control
- Corrosion Inhibitors
- Aeration

Iron/Manganese Removal
- Chemical Oxidation Precipitation
  - Potassium Permanganate
  - Sodium Permanganate
  - Chlorine Dioxide
- Aeration
- Filters

Storage
- Ground Storage
- Elevated Tanks
- Standpipes
- Hydropneumatic Tanks

Cross Connections
- Air Gap
- Vacuum Breakers
- Backflow
- Backpressure
- Backsiphonage
- Cross Connection

Category of Information: Support Systems

Motors
- Single Phase
- Three Phase

Pumps
- Centrifugal
- Positive Displacement (Diaphragm)
- Turbine
- Metering

Pipes
- Ductile Iron
- PVC
- Asbestos Cement

Joints
- Flanged

Valves
- Ball
- Check
- Globe
- Gate
- Pressure Control
- Vacuum Relief
- Butterfly
- Air Release
- Foot
- Altitude

Fittings
- Coupling
- Union
- Plug/Caps
- Corporation
- Curb Stop

Cathodic Protection Devices
- Anode Rod/Bags
- Cathode Rod/Bags
- Rectifiers
- Dissimilar metals – Galvanic Corrosion

Chemical Feeders
- Solids
- Liquids
- Evaporators
- Gas
- Slurry

Safety
- Personal Protection Equipment
- Self Contained Breathing Apparatus
- Confined Space
- MSDS Information
- Traffic Control (Warning Devices; Barricades)
- Hazard Detection
- First Aid/Hygiene

Category of Information: Support Systems (continued)

Measuring/Control

- Signal Generators
  - Magnetic Flowmeter
  - Parshall Flume
  - Rectangular Weir
  - Venturi
  - Propeller Meter
  - Ultrasonic
  - Pitot tube
- Signal Transmitters
  - Electric
  - Pneumatic
  - Hydraulic
- Meters
  - Electrical - Multi – VOM
  - Electrical - Multi – MA
- Alarms
- Controls
  - Pneumatic
  - Hydraulic
  - Timers

Security

- Attack
  - Prevention
  - Detection
  - Recovery

Category of Information: Lab Tests

Lab Tests

- Alkalinity
- Calcium
- Disinfectant residual
- Disinfectant demand
- Fluoride
- Orthophosphate
- pH
- Temperature
- Total Coliform
- Total Hardness
- THM
- HAA5
- Turbidity
- Specific Gravity

Category of Information: General Information

Units of Expression

- Definition
- Conversion

Sources and Characteristics

- Characterization
- Quality/quantity
- Physical/chemical/biological characteristics

Electrical Concepts (Basic)

-

Maps/Plans

Grade 2 Water Treatment Operator
Need-To-Know Criteria (Subject Areas)

The following list of categories suggests topics of information that are important to know in order to be a successful and proficient Grade 4 Water Treatment Operator. The list may not be all-inclusive, and knowledge of additional topics may be of benefit to the operator.

Category of Information: Processes

Pre-Treatment
- Screens (Wells; Intake)

Aeration
- Slat tray
- Cascade
- Draft Aerators
  - Induced draft
  - Positive draft
  -

Coagulation/Flocculation
- Mixers-in-line
- Baffles
- *Polymers*
- Coagulants
  - Alum
  - Ferric Chloride and Sulfate

Clarification
- Sedimentation Basins
- Tube settlers

Filtration
- Pressure
- Membrane
- Oxidation
  - Potassium Permanganate
  - Sodium Permanganate
- Point of entry cartridge filter
- Bag

Disinfection
- Gas Chlorinators
- Hypochlorinators
- Chlorine Dioxide
- Mixed Oxidants
- Ultra-violet

Fluoridation
- Fluorosilicic Acid
- Sodium fluoride
- Sodium Fluorosilicate

Taste/Odor Control
- Aeration
- Powdered Activated Carbon
- Oxidation
  - Potassium Permanganate
  - Sodium Permanganate
  - Chlorine
  - Peroxide

Softening
- Chemical Precipitation
- Ion Exchange

Corrosion Control
- Calcium Carbonate Equilibrium
- Corrosion Inhibitors
- Aeration

Iron/Manganese Removal

- Chemical Oxidation Precipitation
  - Potassium Permanganate
  - Sodium Permanganate
  - Chlorine Dioxide
- Aeration
- Filters
- Green Sand

Storage
- Ground Storage
- Elevated Tanks
- Standpipes
- Hydropneumatic Tanks

Sludge Disposal
- Land Application of Solids

Cross Connections
- Air Gap
- Vacuum Breakers
- Backflow
- Backpressure
- Backsiphonage
- Cross Connection

Category of Information: Support Systems

Motors
- Single Phase
- Three Phase
- Variable Speed

Drives
- Coupled
- Direct

Pumps
- Centrifugal
- Positive Displacement (Diaphragm)
- Turbine
- Metering

Category of Information: Support Systems (continued)

Generators
- AC

Pipes
- Ductile Iron
- PVC
- Asbestos Cement

Joints
- Flanged
- Compression/Dresser

Valves
- Ball
- Check
- Globe
- Gate
- Plug
- Pressure Control
- Vacuum Relief
- Butterfly
- Air Release
- Foot
- Altitude

Fittings
- Coupling
- Union
- Plug/Caps
- Corporation
- Curb Stop

Cathodic Protection Devices
- Anode Rod/Bags
- Cathode Rod/Bags
- Rectifiers
- Dissimilar metals – Galvanic Corrosion

Measuring/Control
- Signal Generators
  - Magnetic Flowmeter
  - Parshall Flume
  - Proportional Weir
  - Rectangular Weir
  - Venturi
  - Propeller Meter
  - Ultrasonic
  - Pitot tube
- Signal Transmitters
  - Electric
  - Pneumatic
  - Hydraulic

Engines
- Gasoline & Diesel

Measuring/Control (continued)
- Signal Receivers
  - Counters
  - Indicators
  - Log Scale Indicators
  - Totalizers
  - Recorders
- Meters
  - Hydraulic/Rotameters
  - Electrical – Amp
  - Electrical – Watt
  - Electrical - Multi – VOM
  - Electrical - Multi – MA
- Alarms
- Controls
  - Pneumatic
  - Float
  - Hydraulic
  - Electrical
  - Telemetry
  - Timers

Chemical Feeders
- Solids
- Liquids
- Gas
- Slurry

Rolling Stock
- Service Vehicles
- Trucks

Safety
- Personal Protection Equipment
- Self Contained Breathing Apparatus
- Confined Space
- MSDS Information
- Traffic Control (Warning Devices; Barricades)
- Hazard Detection
- First Aid/Hygiene

Security
- Attack
  - Prevention
  - Detection
  - Recovery

Category of Information: Lab Tests

Lab Tests
- Alkalinity
- Calcium
- Disinfectant residual
- Disinfectant demand
- Fluoride
- Iron
- Manganese
- Orthophosphate
- pH
- Temperature
- Threshold Odor Number
- Total Coliform
- THM
- HAA5
- Total Hardness
- Turbidity (NTU)
- CO_2
- Specific Gravity

Category of Information: General Information

Units of Expression
- Definition
- Conversion

Sources and Characteristics
- Characterization
- Quality/quantity
- Physical/chemical/biological characteristics

Electrical Concepts (Basic)
-

Hydraulic Concepts (Basic)
-

Maps/Plans

Grade 3 Water Treatment Operator
Need-To-Know Criteria (Subject Areas)

The following list of categories suggests topics of information that are important to know in order to be a successful and proficient Grade 4 Water Treatment Operator. The list may not be all-inclusive, and knowledge of additional topics may be of benefit to the operator.

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- Slat tray
- Cascade
- Draft Aerators
  - Induced draft
  - Positive draft

Coagulation/Flocculation
- Mixers-in-line
- Mechanical
- Baffles
- Polymers
- Coagulants
  - Alum
  - Ferric Chloride and Sulfate
  - Polyaluminum Chloride

Clarification
- Pre-sedimentation
- Sedimentation Basins
- Upflow Solids Clarifiers
- Tube settlers

Filtration
- Rapid Sand
- Mixed Media
- Pressure
- Slow Sand
- Membrane
- Oxidation
  - Potassium Permanganate
  - Sodium Permanganate
- Point of entry cartridge filter
- Bag

Disinfection
- Gas Chlorinators
- Hypochlorinators
- Ozonators
- Chlorine Dioxide
- Mixed Oxidants
- Ultra-violet

Fluoridation
- Fluorosilicic Acid
- Sodium fluoride
- Sodium Fluorosilicate

Taste/Odor Control
- Aeration
- Powdered Activated Carbon
- GAC Contactors
- Oxidation
  - Potassium Permanganate
  - Sodium Permanganate
  - Chlorine
  - Peroxide

Softening
- Chemical Precipitation
- Ion Exchange

Corrosion Control
- Calcium Carbonate Equilibrium
- Corrosion Inhibitors
- Aeration

Iron/Manganese Removal

- Chemical Oxidation Precipitation
  - Potassium Permanganate
  - Sodium Permanganate
  - Chlorine Dioxide
- Aeration
- Filters
- Green Sand

Storage
- Ground Storage
- Elevated Tanks
- Standpipes
- Hydropneumatic Tanks

Recirculation
- Water Systems
- Sludge Systems

Sludge Disposal
- Drying Beds
- Filter Press
- Land Disposal
- Belt Press
- Landfill Solids
- Land Application of Solids

Cross Connections
- Air Gap
- Vacuum Breakers
- Backflow
- Backpressure
- Backsiphonage
- Cross Connection

Category of Information: Support Systems

Motors
- Single Phase
- Three Phase
- Variable Speed

Drives
- Coupled
- Direct

Pumps
- Air Lift
- Centrifugal
- Positive Displacement (Piston Plunger; Cavity; Diaphragm)
- Turbine
- Metering

Blowers and Compressors
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Generators
- AC & DC

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- Ductile Iron
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Joints
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  - Log Scale Indicators
  - Totalizers
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  - Hydraulic/Rotameters
  - Electrical – Amp
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  - Electrical - Multi – VOM
  - Electrical - Multi - MA
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  - Pneumatic
  - Float
  - Hydraulic
  - Electrical
  - Telemetry
  - Timers

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- Liquids
- Evaporators
- Gas
- Slurry

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- Trucks
- Portable Pumps
- Generators

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- Self Contained Breathing Apparatus
- Confined Space
- MSDS Information
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- Hazard Detection
- First Aid/Hygiene

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Category of Information: Lab Tests

Lab Tests

- Alkalinity
- Calcium
- Disinfectant residual
- Disinfectant demand
- Fluoride
- Iron
- Jar Test
    - Maximum Gradient
    - Velocity Gradient
    - Viscosity of Water
- Manganese
- Orthophosphate
- pH
- Specific Conductance
- Temperature
- Threshold Odor Number
- Total Coliform
- Total Hardness
- Turbidity (NTU)
- CO_2
- Specific Gravity
- THM
- HAA5

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- Signal Receivers
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  - Indicators
  - Log Scale Indicators
  - Totalizers
  - Recorders
- Meters
  - Hydraulic/Rotameters
  - Electrical – Amp
  - Electrical – Watt
  - Electrical - Multi – VOM
  - Electrical - Multi - MA
- Alarms
- Controls
  - Pneumatic
  - Float
  - Hydraulic
  - Electrical
  - Telemetry
  - Timers

Chemical Feeders
- Solids
- Liquids
- Evaporators
- Gas
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Hydraulic Concepts (Basic)

-

Maps/Plans

Suggested Water Treatment Exam References

The following are approved as reference sources for the water treatment examinations. Operators should use the latest edition of these reference sources to prepare for the exam.

Textbooks

American Water Works Association (AWWA) Web site: www.awwa.org
Principles and Practices of Water Supply Operations Series:

- Water Sources
- Water Treatment
- Water Transmission and Distribution
- Water Quality
- Basic Science Concepts and Applications

Other AWWA References:

- Water Quality and Treatment
- Water System Security, A Field Guide

Association of State Drinking Water Administrators (ASDWA) and National Rural Water Association (NRWA) Web site: www.asdwa.org (available online in PDF format;

- Security Vulnerability Self Assessment Guide for Small Drinking Water Systems

California State University, Sacramento (CSUS) Foundation, Office of Water Programs
(www.owp.csus.edu)

- **Water Treatment Plant Operation, Volumes I and II**
- **Manage for Success**

Regulations

- Code of Federal Regulations, Title 40, Part 141 (www.gpo.gov)
- Community Public Water Systems Design Criteria, State of Tennessee, Department of Environment and Conservation, Division of Water Supply, Nashville, 2008.
- Regulations for Public Water Systems and Drinking Water Quality, State of Tennessee, Department of Environment and Conservation, Division of Water Supply, Nashville. June 2009.
- Rules Governing Water and Wastewater Operator Certification, State of Tennessee, Department of Environment and Conservation, Board of Certification for Water and Wastewater Operators, Nashville, TN, December 2009, Section 1200-5-3.

Study Guides

American Water Works Association, Operator Certification Study Guide: A Guide to Preparing for Water Treatment and Distribution Operator Certification Exams (www.awwa.org;

Record Category		Time frame required to keep records		Source
Microbiological Records				1200-5-1-.20(1)(a)
Routine distribution		5 years		
Line repair records		5 years		1200-5-1-.17(8)(a)
New line records		5 years		
Bacteriological sampling plan		Keep updated, at least every 3 years		
Chemical Analysis				1200-5-1-.20(1)(a)
Inorganics/ secondaries		10 years		
SOC's		10 years		
VOC's		10 years		
THM's and HAA5's		10 years		
Radionuclides		10 years		
Lead and copper		12 years		1200-5-1-.33(12)
Miscellaneous				
Action regarding violations		3 years		1200-5-1-.20(1)(b)
Certified Letters to Fire Departments regarding Class C hydrants		5 years		1200-5-1-.17(18)
Complaint file		5 years		1200-5-1-.20(1)(h)
Consumer Confidence Reports		3 years		1200-5-1-.35(h)
Cross connection plans and inspection records		5 years		1200-5-1-.20(1)(h)
Daily worksheets, strip charts, shift logs		5 years		1200-5-1-.20(1)(g)
Disinfection Profile		10 years		
Disinfection SOP		Keep updated		
Distribution map		Keep updated, submit copy to DWS every 5 years		1200-5-1-.17(15)
Distribution SOP		Keep updated		
Emergency Operation Plan		Keep updated		1200-1-5-.34(4)(a)
Facility Maintenance Records		5 years		1200-5-1-.20(1)(h)
Flushing records		Survey to survey or 3 years		1200-5-1-.17(10)
MOR's		5 years		
MSDS		At least 30 years		29 CFR 1910.1020
New tap records		Survey to survey or 3 years		1200-5-1-.17(32)
Notice of Construction		Survey to survey or 3 years		
Plant SOP		Keep updated		
Public Notices		3 years		1200-5-1-.20(i)
Sanitary surveys		10 years		
Storage Tank Inspection Records		5 years		1200-1-5-.17(33), 1200-5-1-.20(1)(h)
Tank maintenance records		Life of tank		1200-1-5-.17(33)
Turbidity analysis: daily worksheets, calibration data and strip charts		5 years		1200-5-1-.20(1)(f)
Variances or Exemptions		5 years		1200-5-1-.20(1)(d)

Section 2

Source Water

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Water Sources & Characteristics

Developing the Water Supply

1

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Learning Objectives

- Hydrologic Cycle
- Characteristics of Groundwater and Surface Water
- Sources of Groundwater and Surface Water
- Water Rights
- Source Development and Protection
- Wells Operation and Maintenance
- Regulatory Publications and Rules

2

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Water Supply Hydrology and the Hydrologic Cycle

- Hydrologic Water Cycle
  - movement of water from the surface of the earth to the atmosphere and back
- Process of evaporation and transpiration
- Condensation forms water vapor droplets
- Precipitation returns water to earth
- Water penetrates ground via infiltration, percolation, and runoff
  - Surface runoff occurs when ground is saturated

3

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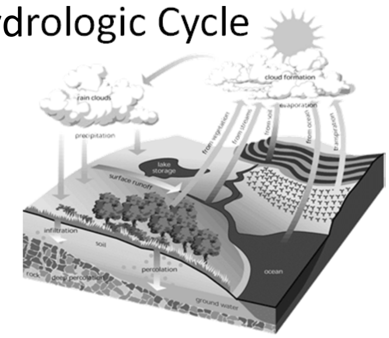
Hydrologic Cycle



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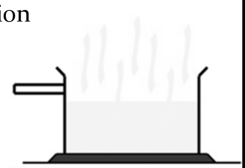
Hydrologic Cycle

- Evaporation and Transpiration
  - Evaporation
    - the changing of liquid to gas (water to water vapor)
  - Water is constantly evaporating from the earth
  - Transpiration
    - the process in which water from the earth is absorbed by plants and transferred to the air through the leaves



5

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Hydrologic Cycle

- Condensation and Precipitation
  - Condensation
    - occurs when water vapor condenses as it cools and forms tiny droplets of water or clouds
  - Precipitation
    - occurs when the droplets become too heavy to stay airborne
    - these droplets fall back to earth as rain, snow, sleet or hail

6

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Hydrologic Cycle

- Infiltration and Percolation
  - As precipitation falls, it soaks into the ground
  - Infiltration
    - the movement of water through the soil
  - Some of the water goes back to the surface due to *capillary action*
    - the movement of water above a water surface
  - The rest percolates (continues downward) to the water table

7

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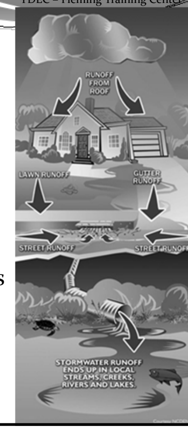
Hydrologic Cycle

- Surface Runoff
  - When the soil can hold no more water, it flows downward over the ground surface
  - It flows into streams or lakes or, eventually, the ocean



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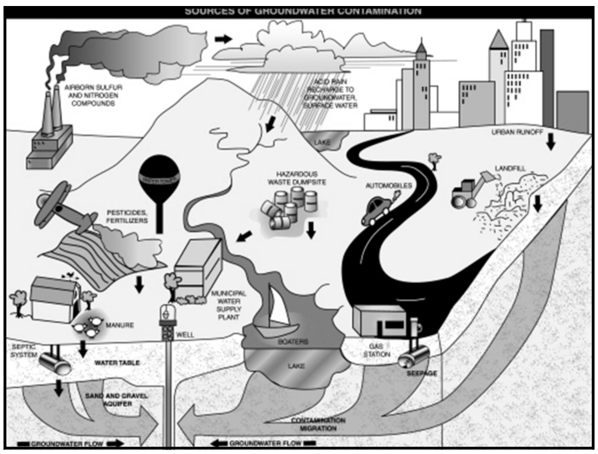

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Groundwater

- Water below the surface
- Hidden resource
- Provides 20% of water used in the US
- Has few contaminants
- Resultant of infiltration and percolation
- Relatively free from micro contamination
- Characterized by:
  - high TDS
    - Fe & Mn
  - high dissolved gases
    - radon, CH_4, H_2S
  - low dissolved oxygen
  - low color
  - high hardness
- Can be influenced by natural and human activities

10

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Groundwater

- Sources
  - Aquifers
    - confined and unconfined
  - Springs
- Half of the world's groundwater resource is located within one mile of the ground surface
- Other half is found in deep aquifers

11

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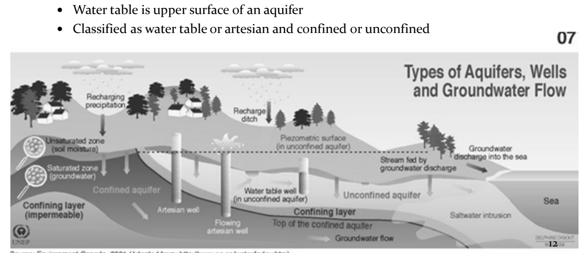
Aquifers

- Characteristics
  - Underground layer of gravel, sand, sandstone, shattered rock, or limestone
  - Impermeable layer of rock, clay or granite keeps water from sinking downward
  - Water table is upper surface of an aquifer
  - Classified as water table or artesian and confined or unconfined



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Aquifers

Unconfined Aquifers

- Upper surface is free to rise and fall
- Water table wells
  - wells constructed to reach an unconfined aquifer
- Amount of water produced varies widely as water table rises and falls in relation to rainfall
- Indicates water table level of surrounding aquifer

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Aquifers

Confined Aquifers

- Also known as Artesian Aquifer
- Permeable layer confined by an upper level and lower level of low permeability material
- Water recharge area usually higher than main part of aquifer
- Water is usually under pressure
- Flowing artesian well
  - pressure causes water to rise above ground surface
- Non-flowing artesian well
  - water doesn't rise to the surface
- Piezometric surface
  - height that water rises

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Aquifers Terms & Materials

- Porosity
  - amount of water the material will hold
- Hydraulic conductivity
  - how easily the water will flow thought the aquifer material
- Both determine how much the aquifer will yield
- Pumping rates are higher in coarser material and cost less
  - less pumping head loss
- Consolidated aquifer formations consist of limestone and fractured rock and produce large quantities of water

15

Groundwater Movement Characteristics

- Movement of water is naturally downhill
- Rainfall percolates down to the water table
- Water moves slowly through soil which removes suspended particles
- Soil acts as a natural filtration process
  - Dissolved pollutants cannot be removed
  - Contaminants can be picked up
- Water table is never completely level

16

Springs

- Occur if water table intersects the ground surface
- Difficult to determine source of springs
- They should be considered contaminated until sanitary survey is conducted
- Flows vary considerably and are influenced by artesian pressures
- Enclose intake in a concrete spring box

17

Surface Water Characteristics

- Higher turbidity
- Suspended solids
- More color
- Microbial contamination
- Impurities in snow and rain
- Impurities from runoff
  - soluble formations such as limestone, gypsum, & rock salt affect characteristics
- Precipitation dissolves gases in atmosphere
- Dust and solids from industrial processes
- Usually soft, low in solids and alkalinity, and pH slightly below 7
- Usually corrosive
- Seasonal changes

18

Surface Water Supply and Operating Problems

- Contamination
- Loss of water source by evaporation & seepage
- Weather (rain and snowfall)
- Exposure to environmental changes
- Icing
- Rainfall intensity and droughts
- Soil composition
- Human influences
- More and varied treatment processes

19

Wells

You surface water people stay awake!
This is a GROUNDWATER people session.

20

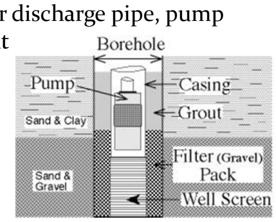
Wells

- Advantages
  - Provide 45% of water used in US
  - Facilities cost less to operate
  - Water is less turbid
  - Contains fewer bacteriological and viral contaminants
    - require less treatment
  - Maintain uniform temperature

21

Parts of a Well

- **Sanitary seal**
  - prevents contamination
  - seal has openings for discharge pipe, pump controls, and air vent
- **Well casing**
  - liner to prevent walls from caving in
  - protects water quality



22

Parts of a Well

- **Well casing vent**
  - prevents pump vacuum and contamination from entering
- **Grout**
  - cement or other material that prevents water from the surface from entering well
- **Intake screen**
  - prevents sand or other material from entering the well and allows water to flow freely

23

Well Terms

- **Static water level**
  - water surface level when no water is being drawn
- **Pumping water level**
  - level at which water drops and stabilizes as it is pumped
- **Drawdown**
  - drop between static and pumping level

24

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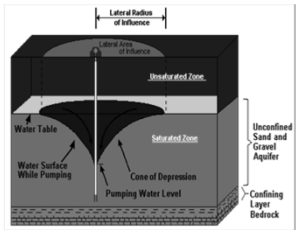
Well Terms

- **Cone of depression**
  - depression in the water level around a well during pumping
- **Zone of influence**
  - length and depth of Radius of Influence
  - determined by Cone of Depression



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Well Terms

- **Residual drawdown**
  - difference between the original water level and water level after pumping has stopped
- **Well yield**
  - rate of water withdrawal that a well can supply over a long period of time
- **Safe yield**
  - maximum amount of water that can be withdrawn continuously during the driest periods
- **Specific gravity**
  - yield per unit of drawdown (can indicate problems)

26

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Well Location and Sanitary Considerations

- Located to produce max yield while being protected
- Deep as possible to prevent contamination from the surface
- If shallow groundwater source, ensure casing and hole grouted
- Prefer a 2 foot deep layer of clay within a 50 foot radius around the well

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Well Operation and Maintenance

- Record Keeping
  - Static water level after pump has been idle for a period of time
  - Pumping water level
  - Drawdown
  - Well production
  - Well yield
  - Time required for recovery after pumping
  - Specific gravity

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Well Operation and Maintenance

- Regular Maintenance
  - Plugging of screen most common problem
    - encrustation of biological growth
    - precipitates of Fe, Mn, and hardness
  - Can be cleaned using hydrochloric acid (muriatic acid)
    - refer to AWWA manual M21
  - Well can fail if screen collapses or corrodes
  - Bacteriological samples should be periodically
  - Disinfection may be needed sometimes

29

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Procedures for Well Abandonment

- Eliminate any physical hazards
- Take measures to prevent groundwater contamination and protect other nearby wells
- Conservation of the aquifer
- Return to geological conditions present before well was constructed
- Private wells must be properly abandoned and plugged
  - can be a cross connection if home is connected to both a well and public water supply
  - it should be permanently disconnected
- **Must be done properly**

30

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Surface Water Source Development

- Includes all tributary streams and drainage basins, natural lakes and artificial reservoirs or impoundments above the point of water supply intake

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Surface Water Source Development

- Factors
  - Quantity
  - Quality
  - Structures
  - Impoundments and reservoirs
  - Site preparation
  - Construction
- Tennessee Public Water System Design Criteria part 3

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Groundwater Source Development

- Includes all water obtained from drilled wells or springs
- General Well Construction Requirements
- Tennessee Public Water System Design Criteria part 3.3

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Safe Drinking Water Act

- SDWA
  - Establishes primary drinking water standards
  - Secondary standards
  - Public notification procedures and requirements
  - Federal Enforcement
  - Established a cooperative program among local, state, and federal agencies
  - EPA executive agency
  - Established MCL's (Maximum Contaminate Level)
  - Established sampling and testing requirements

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Tennessee Water Program

- Governing agency
  - Department of Environment and Conservation Bureau of Environment Division of Water Supply
  - Rules/Regulations
    - Chapter 1200-5-1 Public Water Systems
  - Sanitary surveys
  - Technical assistance
  - Laboratory services
  - Enforcement
  - Environmental Assistance Centers (EACs)
  - Design criteria

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Physical Characteristics of Water

- Relates to sensory qualities of water
- Temperature
  - most familiar characteristic
  - effects lake turnovers, dissolving of chemicals and palatability
  - most desirable drinking water is considered cool
- Turbidity
  - cloudiness of water
  - indicator of health significance
  - operational considerations
  - aesthetics
- Color
  - indicates contamination, dissolved organics, and humic substances that could form THMs
- Taste & odor
  - degradation aesthetic quality

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Chemical Characteristics of Water

- Inorganic
  - pH
    - indicator of acidity or alkalinity
  - Hardness
  - Dissolved oxygen
    - measured in mg/L
  - Dissolved solids
    - toxic minerals include
      - chromium
      - lead
      - mercury
      - silver
      - arsenic
      - barium
      - fluoride
      - nitrate
- Organic
  - Includes
    - pesticides
    - herbicides
    - domestic wastes
    - industrial wastes
    - watershed runoff
  - Can cause taste, odor, and toxicity problems

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Biological Characteristics of Water

- Aquatic life (algae)
- Bacteria
- Coliforms
- Viruses
- Protozoa
- Spores
- Cysts
- Many originate with fecal discharges
- Not easily identified and isolated

38

Radiological Factors in Water

- Development of atomic energy and mining of radioactive materials made it necessary to examine safe limits
- Divided into two categories:
  - Natural and Man-made
- Sources are
  - Natural deposits and Man-made deposits

If someone is glowing, Be Suspicious! ☺

39

Water Source Protection

40

Fundamental Principles

- The quality of source water is influenced by natural and human activities
- It is the responsibility of the operators to minimize harm from both of these
- Surface waters are more influenced by human activities
- Groundwater can also be influenced

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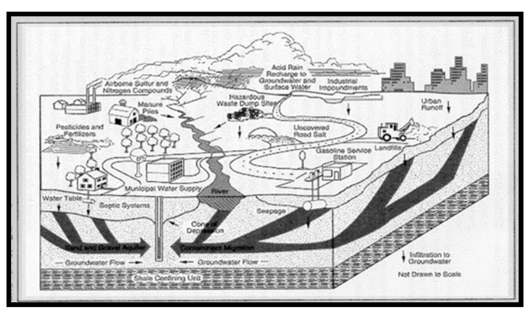
Source of Groundwater & Surface Water Contamination



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Benefits of Source Water Protection Program

- Source control is the first barrier in a multiple-barrier treatment plan
- Water treatment methods are not 100% effective in removing contaminants
  - The risks of residual contaminants can be too high
- As the quality of source water deteriorates, the cost of treatment goes up and can become prohibitive

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Benefits of Source Water Protection Program

- Increase in public confidence
- Decrease in public health risks
- Due to difficulty to analyze, remove, and/or disinfect pathogens with conventional methods, keeping pathogens out of the source water may be the only way of providing protection

44

Developing a Source Water Protection Program

- Inventory and characterize the water source
- Identify pollutant sources and relative impact
- Assess vulnerability of intake to contaminants
- Establish source water protection goals

45

Developing a Source Water Protection Program

- Develop source water protection strategies
- Implement the program
- Monitor and evaluate program effectiveness

46

Developing a Source Water Protection Program

- Identify area that needs protection and who has an interest in protecting it
  - For wellhead protection
    - aquifer delineation
  - For surface water sources
    - watershed mapping

47

Developing a Source Water Protection Program

- Aquifer Delineation (Wellhead Protection Area)
  - Define the land area over the portion of the aquifer that influences the quality of the water
  - Should be identified and inventoried for potential of contamination
  - For microbiological contaminants, a small area is suitable

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Developing a Source Water Protection Program

- Aquifer Delineation (Wellhead Protection Area)
  - Chemical contaminants can travel from several thousand feet for relatively deep wells
  - USGS maps are a good place to start
  - 1986 SDWA amendments require each state to develop a Wellhead Protection Program
  - Limit activities in area to protect well and aquifer from contamination

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Developing a Source Water Protection Program

- Watershed Mapping
  - Surface water sources
  - Watershed is area sloped toward water source that drains to it
  - Watershed should be identified and inventoried for potential sources of contaminantion
  - USGS (United States Geological Survey)

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Developing a Source Water Protection Program

- Watershed Mapping
  - If utility can purchase lands in the watershed, it can limit activities that could affect water quality
  - If land cannot be bought, buffer zones for logging and agriculture operations should be implemented
  - Promote community activities that emphasize protection of watershed

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Developing a Source Water Protection Program

- Identify Pollutant Sources and Relative Impact
  - Sewage disposal
  - Urban, industrial, agricultural and mine runoff
  - Animal population
  - Forestry/soil disturbance runoff
  - Recreation

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Developing a Source Water Protection Program

- Assess Vulnerability of Intake to Contaminants
  - Purpose
    - identify contaminant
    - identify amount of contaminant
    - correlate land use to contaminant level
  - Assessment methods
    - water quality monitoring
    - modeling
    - onsite assessment

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Developing a Source Water Protection Program

- Strategies
  - Land use controls
    - buffer zones
    - land acquisition
    - comprehensive planning
    - watershed/recharge area inspections

54

Developing a Source Water Protection Program

- Vandalism and Terrorism
  - Before 9/11/01, no serious threat
  - Protect intakes
  - Safeguard area around source, if possible
  - Monitoring and surveillance may be required if threat is serious
  - Be alert of suspicious events

55

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Developing a Source Water Protection Program

- Title IV Drinking Water Security and Safety
  - Must have assessment of system
  - Dateline is dependent on sizeo f system
  - ERPs (Emergency Response Plans) are due 6 months after assessment
  - Plans include actions, procedures, and identification of equipment which can prevent or lessen the impact of a terrorist act

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Developing a Source Water Protection Program

- Source of Contamination
  - After WHPA or watershed boundary for a water source has been determined, inventory of potential contaminant sources is to be performed
  - Community volunteer effort along with utility personnel is encouraged
    - volunteer fire dept., citizen group, etc.

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Developing a Source Water Protection Program

- Regulations
  - Tennessee Regulations for Wellhead Protection
    - Section 1200-5-1-.34

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Water Sources and Characteristics Review Questions

1. Draw the basic hydrologic cycle.

2. What is the water table?

3. Define the term aquifer.

4. What two things determine the amount of water an aquifer will yield?
   - ➢
   - ➢

5. Describe the differences in water characteristics of groundwater and surface water.

6. Define the term watershed.

7. List six factors that influence the amount of surface runoff.
   - ➢
   - ➢
   - ➢
   - ➢
   - ➢
   - ➢

8. What is the purpose of an impoundment?

Water Supply Vocabulary

_______1.	Aqueduct	_______8.	Percolation
_______2.	Aquifer	_______9.	Safe Yield
_______3.	Aquifer Recharge Area	_______10.	Spring
_______4.	Artesian Well	_______11.	Surface Runoff
_______5.	Groundwater	_______12.	Surface Water
_______6.	Hydraulic Conductivity	_______13.	Water Table
_______7.	Hydrologic Cycle	_______14.	Water Table Well

A. The movement of water through the pores of soil, usually downward.

B. All water on the surface of the earth.

C. A well in which water pressure forces water up through a hole in the upper confining, or impermeable, layer of an artesian aquifer

D. A conduit, usually of considerable size, used to convey water.

E. The maximum dependable water supply that can be withdrawn continuously from a surface water or groundwater supply.

F. A well constructed in a water-table aquifer.

G. The water cycle; the movement of water to and from the earth's surface.

H. A porous, water-bearing geological formation.

I. A location where groundwater emerges on the surface of the ground.

J. The water that reaches a stream by traveling over the soil surface.

K. Subsurface water occupying the saturation zone, from which wells and springs are fed.

L. The land above an aquifer that contributes water to it.

M. A measure of the ease with which water will flow through geological formations.

N. The upper surface of an aquifer.

Parts of a Well – Matching

Draw a line from the term to its definition:

Sanitary Seal	Allows water to flow freely from an aquifer to a well; keeps sand out of a well.
Well Casing	Concrete area placed around the casing to support pumping equipment.
Intake Screen	A liner placed in the bore hole of a well to prevent the walls from caving in.
Grout	Prevents contamination from entering the well at the surface.
Well Slab	Seals the space between the casing and the bore hole.

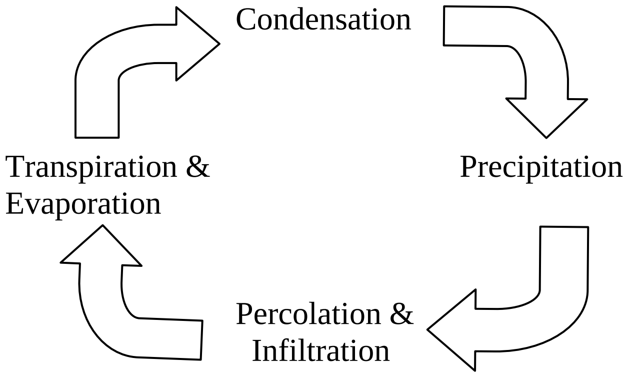
Well Terms – Matching

Draw a line from the term to its definition:

Static Water Level	Inverted cone-shaped depression in water level while pump is operating.
Pumping Water Level	Water level when no water is being pumped from the aquifer.
Drawdown	Difference between original water level and the level after pumping has stopped.
Cone of Depression	Well yield ÷ drawdown.
Zone of Influence	Level to which water drops and stabilizes as it is pumped.
Residual Drawdown	Length and depth of radius of influence as determined by the cone of depression.
Well Yield	The drop between the static water level and the pumping water level.
Specific Capacity	The rate of water withdrawal that can be supplied over a period of time.

Answers to Water Sources and Characteristics Review Questions

1.



2. The water table is the upper surface of an aquifer.

3. An aquifer is a porous, water-bearing geological formation.

4. The porosity and hydraulic conductivity determine the amount of water an aquifer will yield.

5. Groundwater:
   - High dissolved solids
   - Dissolved gasses
   - Low color
   - High hardness
   - Free from microbes

   Surface water:
   - Suspended solids
   - Higher turbidity
   - Higher color
   - Lower hardness
   - Microbial contamination

6. A watershed is the land area that is sloped toward a water source and drains into it.

7. Six factors influencing the amount of surface runoff are:
   rainfall intensity, rainfall duration, soil composition, soil moisture, ground slope, vegetation cover

8. An impoundment stores water for use during water deficiencies.

Answers to Water Supply Vocabulary:

1. D
2. H
3. L
4. C
5. K
6. M
7. G
8. A
9. E
10. I
11. J
12. B
13. N
14. F

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Specific Capacity	The rate of water withdrawal that can be supplied over a period of time.

Section 3

Math Review

Solving for the Unknown

Basics – finding x

1. $8.1 = (3)(x)(1.5)$

2. $(0.785)(0.33)(0.33)(x) = 0.49$

3. $\frac{233}{x} = 44$

4. $940 = \frac{x}{(0.785)(90)(90)}$

5. $x = \frac{(165)(3)(8.34)}{0.5}$

6. $56.5 = \frac{3800}{(x)(8.34)}$

7. $114 = \frac{(230)(1.15)(8.34)}{(0.785)(70)(70)(x)}$

8. $2 = \frac{x}{180}$

9. $46 = \frac{(105)(x)(8.34)}{(0.785)(100)(100)(4)}$

10. $2.4 = \frac{(0.785)(5)(5)(4)(7.48)}{x}$

11. $19,747 = (20)(12)(x)(7.48)$

12. $\frac{(15)(12)(1.25)(7.48)}{x} = 337$

13. $\frac{x}{(4.5)(8.34)} = 213$

14. $\frac{x}{246} = 2.4$

15. $6 = \frac{(x)(0.18)(8.34)}{(65)(1.3)(8.34)}$

16. $\frac{(3000)(3.6)(8.34)}{(0.785)(x)} = 23.4$

17. $109 = \frac{x}{(0.785)(80)(80)}$

18. $(x)(3.7)(8.34) = 3620$

19. $2.5 = \frac{1,270,000}{x}$

20. $0.59 = \frac{(170)(2.42)(8.34)}{(1980)(x)(8.34)}$

Finding x^2

21. $(0.785)(D^2) = 5024$

22. $(x^2)(10)(7.48) = 10{,}771.2$

23. $51 = \frac{64{,}000}{(0.785)(D^2)}$

24. $(0.785)(D^2) = 0.54$

25. $2.1 = \frac{(0.785)(D^2)(15)(7.48)}{(0.785)(80)(80)}$

Percent Practice Problems

Convert the following fractions to decimals:

1. $\frac{3}{4}$

2. $\frac{5}{8}$

3. $\frac{1}{4}$

4. $\frac{1}{2}$

Convert the following percents to decimals:

5. 35%

6. 99%

7. 0.5%

8. 30.6%

Convert the following decimals to percents:

9. 0.65

10. 0.125

11. 1.0

12. 0.05

Calculate the following:

13. 15% of 125

14. 22% of 450

15. 473 is what % of 2365?

16. 1.3 is what % of 6.5?

Answers for Solving for the Unknown

Basics – Finding x

1. 1.8
2. 5.73
3. 5.29
4. 5,976,990
5. 8256.6
6. 8.06
7. 0.005
8. 360
9. 1649.4
10. 244.7
11. 10.99
12. 4.99
13. 7993.89
14. 590.4
15. 2817
16. 4903.5
17. 547,616
18. 117
19. 508,000
20. 0.35

Finding x^2

21. 80
22. 12
23. 39.98
24. 0.83
25. 10.94

Percent Practice Problems

1. 0.75
2. 0.625
3. 0.25
4. 0.5
5. 0.35
6. 0.99
7. 0.005
8. 0.306
9. 65%
10. 12.5%
11. 100%
12. 5%
13. 18.75
14. 99
15. 20%
16. 20%

Area, Volume and Conversions

Introduction to Water Treatment

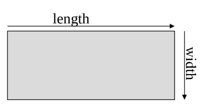
Area

- surface of an object
- two dimensional
- measured in square inches, square feet, square meters, etc.

Area Formulas

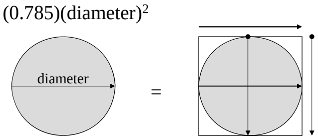
- Rectangle

A = (length)(width)



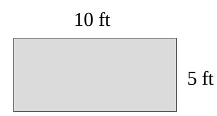
- Circle

A = (0.785)(diameter)^2



Diameter is equal to length and width of a square and a circle takes up 78.5% of square

Area of a Rectangle

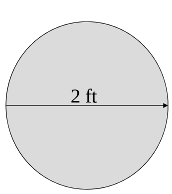


A = (l)(w)

A = (10 ft)(5 ft)

A = 50 ft^2

Area of a Circle



Diameter = 2 ft

A = (0.785)(D)^2

A = (0.785)(2ft)(2ft)

A = 3.14 ft^2

Volume

- The amount of space an object occupies
- Volume = (area)(third dimension) or

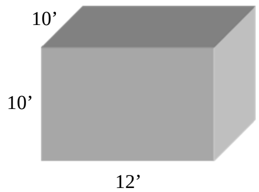
  V = (l)(w)(d)
- Measured in cubic inches, cubic feet, gallons, acre-feet, etc.

Volume of a Rectangular Tank

V = (length)(width)(depth)

V = (12ft)(10ft)(10ft)

V = 1200 ft^3

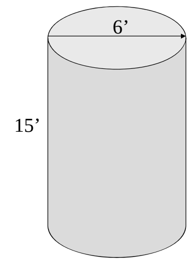


Volume of a Cylinder

V = (0.785)$(D)^2$(height)

V = (0.785)(6ft)(6ft)(15ft)

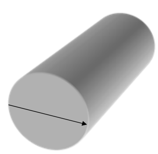
V = 424 ft^3



Note

- When calculating area and volume, if you are given a pipe diameter in inches, convert it to feet.

$8\ \cancel{in.} \times \frac{1\ ft}{12\ \cancel{in}} = 0.6667\ ft$

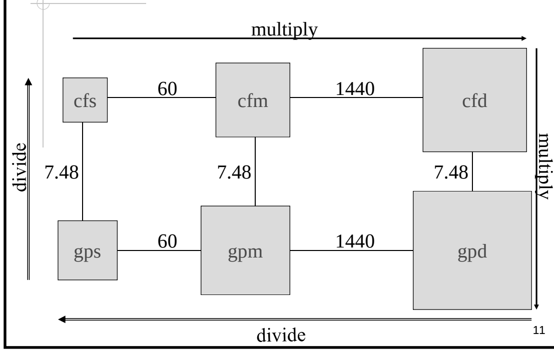


Diameter = 8 in

Conversions

- Need to know:
- The number that relates the two units
  - Ex: 12 inches in a foot, 454 grams in a pound, 3785 mL in a gallon
- Whether to multiply or divide
  - Ex: smaller to larger or larger to smaller

Flow Conversions – Box Method



Dimensional Analysis

- Dimensional analysis can be used to make sure a calculation is set up correctly
- The units on one side of the equal sign must equal the units on the other side

$$\frac{ft^3}{sec} = \frac{(ft)(ft)(ft)}{sec}$$

Dimensional Analysis

- Dimensional analysis can be used to make sure you are finished with your calculation
- If units are written in abbreviated form, write them out in vertical format, gpm=gal/min

$$\frac{\cancel{(ft)(ft)(ft)}}{min} \times \frac{gal}{\cancel{ft^3}} = \frac{gal}{min}$$

13

Math Problem Strategies

Use these rules of operation to approach math problems (*especially when working with formulas*):

1) Work from left to right.
2) Do all the work inside the parentheses first.
3) Do all the multiplication/division above the line (numerator) and below the line (denominator).
4) Then do all the addition and subtraction above and below the line.
5) Perform the division (divided the numerator by the denominator).

Strategy for solving word problems:

1) Read the problem, disregard the numbers (What type of problem is it? What am I asked to find?)
2) Refer to the diagram, if provided. If there isn't one, draw your own.
3) What information do I need to solve the problem, and how is it given in the statement of the problem?
4) Work it out.
5) Does it make sense?

It might be helpful to write out everything that is known in one column and the unknown (what am I asked to find?) in another column. Identify the correct formula and write it in the middle, plug in the numbers and solve.

<u>Known</u>

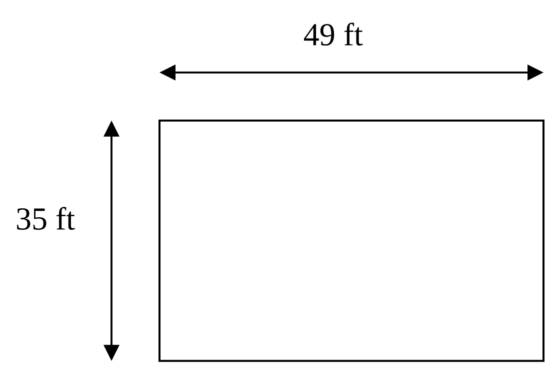
Length = 35 ft
Width = 49 ft

<u>Unknown</u>

Area = ?

$A = (l)(w)$

$A = (35\text{ ft})(49\text{ ft})$
$A = 1715\text{ ft}^2$

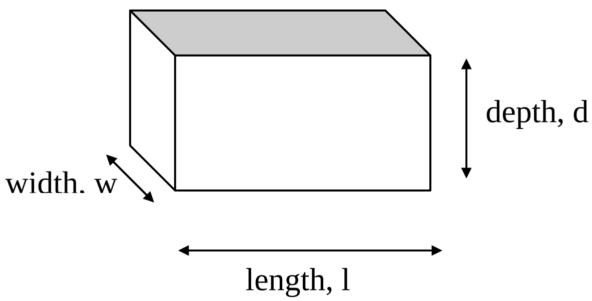


*****Remember: make sure measurements agree; if diameter of pipe is in inches then change to feet; if flow is in MGD and you need feet or feet/sec then change to ft^3/sec before you plug values into formula.***

mega (M)		kilo (k)	hecto (h)	deka (da)	no prefix	deci (d)	centi (c)	milli (m)		micro (µ)
1,000,000	. .	1,000	100	10	1	$^{1}/_{10}$	$^{1}/_{100}$	$^{1}/_{1,000}$	. .	$^{1}/_{1,000,000}$

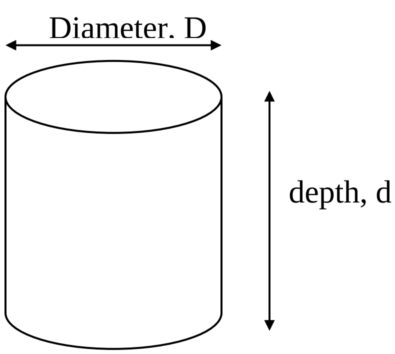
Tank Volume Calculations: Most tank volumes calculations are for tanks that are either rectangular or cylindrical in shape.

Rectangular Tank



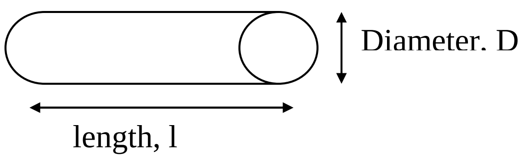
Volume = (l)(w)(d)

Cylindrical Tank



Volume = (0.785) (D)^2 (d)

Portion of a Pipeline



Volume = (0.785) (D)^2 (l)

Area, Volume and Conversions

AREA

1. A basin has a length of 45 feet and a width of 12 feet. Calculate the area in ft^2.

2. A tank has a length of 90 feet, a width of 25 feet, and a depth of 10 feet. Calculate the surface area in ft^2.

3. Calculate the cross-sectional area (in ft^2) for a 2 foot main that has just been laid.

4. Calculate the cross-sectional area (in ft^2) for a 24" main that has just been laid.

5. Calculate the cross-sectional area (in ft^2) for a 2 inch line that has just been laid.

VOLUME

6. Calculate the volume (in ft^3) of a tank that measures 10 feet by 10 feet by 10 feet.

7. Calculate the volume (in gallons) of a basin that measures 22 feet by 11 feet by 5 feet deep.

8. Calculate the volume (in gallons) of water in a tank that is 254 feet long, 62 feet wide, and 10 feet deep if the tank only contains 2 feet of water.

9. Calculate the volume of water in a tank (in gallons) that is 12 feet long by 6 feet wide by 5 feet deep and contains 8 inches of water.

10. Calculate the maximum volume of water (in gallons) for a kids' swimming pool that measures 6 feet across and can hold 18 inches of water.

11. How much water (in gallons) can a barrel hold if it measures 3.5 feet in diameter and can hold water to a depth of 4 feet?

12. A water main has just been laid and needs to be disinfected. The main is 30” in diameter and has a length of 0.25 miles. How many gallons of water will it hold?

13. A water main is 10” in diameter and has a length of 5,000 feet. How many million gallons of water will it hold?

14. A 3 million gallon water tank needs to be disinfected. The method you will use requires you to figure 5% of the tank volume. How many gallons will this be?

15. What is 5% of a 1.2 MG tank?

CONVERSIONS

16. How many seconds in 1 minute?

17. How many minutes in 1 hour?

18. How many hours in 1 day?

19. How many minutes in 1 day?

20. The flow through a pipe is 3.6 cfs. What is the flow in gps?

21. The flow through a pipe is 2.4 cfs. What is the flow in gpm?

22. A pump produces 22 gpm. How many cubic feet per hour is that?

23. A treatment plant produces a flow of 6.31 MGD. What is the flow in gpm?

24. A pump produces 700 gpm. How many MGD will the pump flow?

25. A three-eighths mile segment of pipeline is to be repaired. How many feet of pipeline is this?

26. If there is a 2,200 gallon tank full of water, how many pounds of water is in the tank?

ANSWERS:

1. 540 ft^2
2. 2,250 ft^2
3. 3.14 ft^2
4. 3.14 ft^2
5. 0.0218 ft^2
6. 1,000 ft^3
7. 9,050.8 gal
8. 235,590 gal
9. 359 gal
10. 317 gal
11. 288 gal
12. 48,442 gal
13. 0.02 MG
14. 150,000 gal
15. 60,000 gal or 0.06 MG
16. 60
17. 60
18. 24
19. 1440
20. 26.9 gps
21. 1,077 gpm
22. 176.5 ft^3/hr
23. 4,382 gpm
24. 1.008 MGD
25. 1,980 ft
26. 18,348 lbs

Section 3

Basic Math Review for Water Treatment
Flow Conversions
(round to the nearest tenth)

1. Express a flow of 5 cfs in terms of gpm.

2. What is 38 gps expressed as gpd?

3. Convert a flow of 4,270,000 gpd to cfm.

4. What is 5.6 MGD expressed as ft^3/sec?

5. Express 423,690 cfd as gpm.

6. Convert 2730 gpm to gpd.

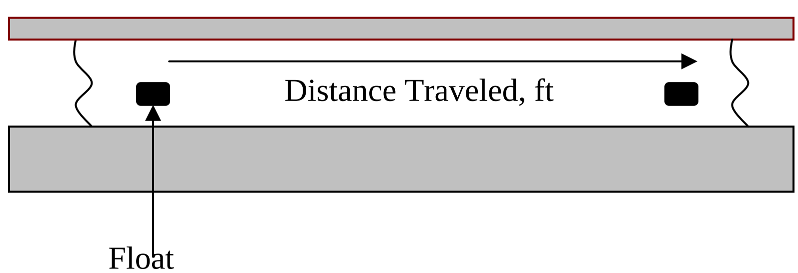
Applied Math for Water Treatment
Flow and Velocity

Velocity

1. A cork is placed in a channel and travels 370 feet in 2 minutes. What is the velocity of the water in the channel, ft/min?

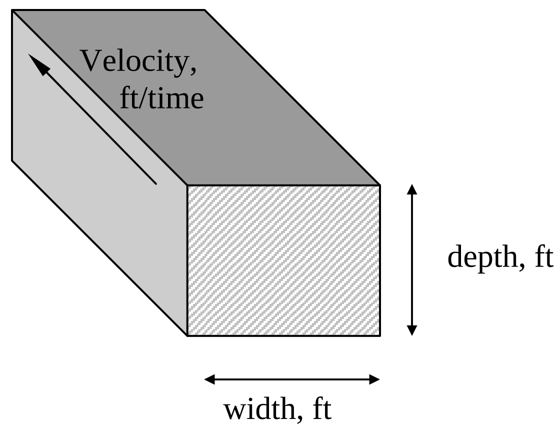
2. A float travels 300 feet in a channel in 2 minutes and 14 seconds. What is the velocity in the channel, ft/sec?

3. The distance between manhole #1 and manhole #2 is 105 feet. A fishing bobber is dropped into manhole #1 and enters manhole #2 in 30 seconds. What is the velocity of the water in the pipe in ft/min?



$$\text{Velocity} = \frac{\text{Distance Traveled, ft}}{\text{Duration of Test, min}}$$

$$= \text{ft/min}$$



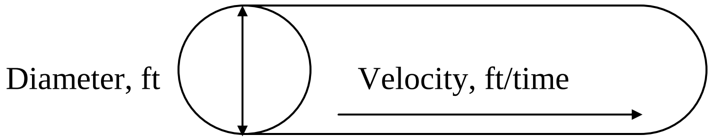
$$\underset{ft^3/time}{Q} = \underset{(ft)(ft)}{(A)} \; \underset{(ft/time)}{(V)}$$

Flow in a channel

4. A channel 48 inches wide has water flowing to a depth of 1.5 feet. If the velocity of the water is 2.8 ft/sec, what is the flow in the channel in cu ft/sec?

5. A channel 3 feet wide has water flowing to a depth of 2.5 feet. If the velocity through the channel is 120 feet/min, what is the flow rate in cu ft/min? in MGD?

6. A channel is 3 feet wide and has water flowing at a velocity of 1.5 ft/sec. If the flow through the channel is 8.1 ft^3/sec, what is the depth of the water in the channel in feet?



$$\underset{ft^3/time}{Q} = \underset{ft^2}{(A)} \quad \underset{(ft/time)}{(V)}$$

$$\underset{ft^3/time}{Q} = (0.785)\underset{(ft)(ft)}{(D)^2}\ \underset{(ft/time)}{(vel)}$$

<u>Flow through a full pipe</u>

7. The flow through a 2 ft diameter pipeline is moving at a velocity of 3.2 ft/sec. What is the flow rate in cu ft/sec?

8. The flow through a 6 inch diameter pipeline is moving at a velocity of 3 ft/sec. What is the flow rate in ft^3/sec?

9. The flow through a pipe is 0.7 ft^3/sec. If the velocity of the flow is 3.6 ft/sec, and the pipe is flowing full, what is the diameter of the pipe in inches?

10. An 8 inch diameter pipeline has water flowing at a velocity of 3.4 ft/sec. What is the flow rate in gpm?

Solving for the Unknown

Basics – finding x

1. $8.1 = (3)(x)(1.5)$

$8.1 = (4.5)(x)$

$\frac{8.1}{4.5} = x$

$\boxed{1.8 = x}$

2. $(0.785)(0.33)(0.33)(x) = 0.49$

$(0.0854865)(x) = 0.49$

$x = \frac{0.49}{0.0854865}$

$\boxed{x = 5.73}$

3. $\frac{233}{x} = 44$

$233 = (44)(x)$

$\frac{233}{44} = x$

$\boxed{5.29 = x}$

4. $940 = \frac{x}{(0.785)(90)(90)}$

$940 = \frac{x}{6358.5}$

$(940)(6358.5) = x$

$\boxed{5{,}976{,}990 = x}$

5. $x = \frac{(165)(3)(8.34)}{0.5}$

$x = \frac{4128.3}{0.5}$

$\boxed{x = 8256.6}$

6. $56.5 = \frac{3800}{(x)(8.34)}$

$(56.5)(8.34)(x) = 3800$

$(471.21)(x) = 3800$

$x = \frac{3800}{471.21}$

$\boxed{x = 8.06}$

7. $114 = \frac{(230)(1.15)(8.34)}{(0.785)(70)(70)(x)}$

$x = \frac{(230)(1.15)(8.34)}{(0.785)(70)(70)(114)}$

$x =$

8. $2 = \frac{x}{180}$

$(2)(180) = x$

$\boxed{360 = x}$

9. $46 = \frac{(105)(x)(8.34)}{(0.785)(100)(100)(4)}$

$46 = \frac{(875.7)(x)}{31400}$

$(46)(31400) = (875.7)(x)$

$\frac{(46)(31400)}{875.7} = x$

$\boxed{1649.4 = x}$

10. $2.4 = \frac{(0.785)(5)(5)(4)(7.48)}{x}$

$(2.4)(x) = (0.785)(5)(5)(4)(7.48)$

$x = \frac{(0.785)(5)(5)(4)(7.48)}{2.4}$

$\boxed{x = 245}$

11. $19{,}747 = (20)(12)(x)(7.48)$

$19{,}747 = (1795.2)(x)$

$\frac{19747}{1795.2} = x$

$10.99 = x$

12. $\frac{(15)(12)(1.25)(7.48)}{x} = 337$

$(15)(12)(1.25)(7.48) = (337)(x)$

$\frac{(15)(12)(1.25)(7.48)}{337} = x$

$4.99 = x$

13. $\frac{x}{(4.5)(8.34)} = 213$

$x = (213)(4.5)(8.34)$

$x = 7993.89$

14. $\frac{x}{246} = 2.4$

$x = (2.4)(246)$

$x = 590.4$

15. $6 = \frac{(x)(0.18)(8.34)}{(65)(1.3)(8.34)}$

$\frac{(6)(65)(1.3)(8.34)}{(0.18)(8.34)} = x$

$2817 = x$

16. $\frac{(3000)(3.6)(8.34)}{(0.785)(x)} = 23.4$

$90072 = (23.4)(0.785)(x)$

$90072 = (18.369)(x)$

$\frac{90072}{18.369} = x$

$4903.5 = x$

17. $109 = \frac{x}{(0.785)(80)(80)}$

$(109)(0.785)(80)(80) = x$

$547616 = x$

18. $(x)(3.7)(8.34) = 3620$

$x = \frac{3620}{(3.7)(8.34)}$

$x = 117$

19. $2.5 = \frac{1{,}270{,}000}{x}$

$(2.5)(x) = 1{,}270{,}000$

$x = \frac{1270000}{2.5}$

$x = 508{,}000$

20. $0.59 = \frac{(170)(2.42)(8.34)}{(1980)(x)(8.34)}$

$0.59 = \frac{3431.076}{(16513.2)(x)}$

$(0.59)(16513.2)(x) = 3431.076$

$(9742.788)(x) = 3431.076$

$x = \frac{3431.076}{9742.788}$

$x = 0.35$

Finding x^2

21. $(0.785)(D^2) = 5024$

$$D^2 = \frac{5024}{0.785}$$
$$\sqrt{D^2} = \sqrt{6400}$$
$$D = 80$$

22. $(x^2)(10)(7.48) = 10{,}771.2$

$$(x^2)(74.8) = 10771.2$$
$$(x^2) = \frac{10771.2}{74.8}$$
$$\sqrt{x^2} = \sqrt{144}$$
$$x = 12$$

23. $51 = \dfrac{64{,}000}{(0.785)(D^2)}$

$$(51)(0.785)(D^2) = 64{,}000$$
$$D^2 = \frac{64000}{(51)(0.785)}$$
$$\sqrt{D^2} = \sqrt{1598.6}$$
$$D = 39.98$$

24. $(0.785)(D^2) = 0.54$

$$D^2 = \frac{0.54}{0.785}$$
$$\sqrt{D^2} = \sqrt{0.6879}$$
$$D = 0.829$$

25. $2.1 = \dfrac{(0.785)(D^2)(15)(7.48)}{(0.785)(80)(80)}$

$$2.1 = \frac{(88.077)(D^2)}{5024}$$
$$(2.1)(5024) = (88.077)(D^2)$$
$$\frac{(2.1)(5024)}{88.077} = D^2$$
$$\sqrt{119.786} = \sqrt{D^2}$$
$$10.94 = D$$

Percent Practice Problems

Convert the following fractions to decimals:

1. ¾ 0.75
2. ⅝ 0.625
3. ¼ 0.25
4. ½ 0.5

Convert the following percents to decimals:

5. 35% $\frac{35}{100} =$ 0.35
6. 99% $\frac{99}{100} =$ 0.99
7. 0.5% $\frac{0.5}{100} =$ 0.005
8. 30.6% $\frac{30.6}{100} =$ 0.306

Convert the following decimals to percents:

9. 0.65 (0.65)(100) = 65%
10. 0.125 (0.125)(100) = 12.5%
11. 1.0 (1.0)(100) = 100%
12. 0.05 (0.05)(100) = 5%

Calculate the following: "of" means multiply; "is" means equal to

13. 15% of 125 (0.15)(125) = 18.75
14. 22% of 450 (0.22)(450) = 99
15. 473 is what % of 2365? 473 = (%)(2365) → $\frac{473}{2365} = x$
    0.2 = x
    (0.2)(100) = x
    20% = x
16. 1.3 is what % of 6.5? 1.3 = (x)(6.5)
    $\frac{1.3}{6.5} = x$
    0.2 = x
    20% = x

Area, Volume and Conversions

AREA

1. A basin has a length of 45 feet and a width of 12 feet. Calculate the area in ft^2.

$$\text{Area} = (\text{length})(\text{width})$$
$$A = (45\ ft)(12\ ft)$$
$$A = 540\ ft^2$$

2. A tank has a length of 90 feet, a width of 25 feet, and a depth of 10 feet. Calculate the surface area in ft^2.

$$A = (90\ ft)(25\ ft)$$
$$A = 2250\ ft^2$$

3. Calculate the cross-sectional area (in ft^2) for a 2 foot main that has just been laid.

$$A = (0.785)(\text{diameter})^2$$
$$A = (0.785)(2\ ft)^2$$
$$A = 3.14\ ft^2$$

4. Calculate the cross-sectional area (in ft^2) for a 24" main that has just been laid.

$$A = (0.785)(2\ ft^2) \qquad 24\ in = 2\ ft$$
$$A = 3.14\ ft^2$$

5. Calculate the cross-sectional area (in ft^2) for a 2 inch line that has just been laid.

$$A = (0.785)(0.1667\ ft)^2 \qquad \frac{2\ in}{} \bigg| \frac{1\ ft}{12\ in} = 0.1667\ ft$$
$$A = 0.022\ ft^2$$

VOLUME

6. Calculate the volume (in ft^3) of a tank that measures 10 feet by 10 feet by 10 feet.

Volume = (length)(width)(depth)

Vol = (10 ft)(10 ft)(10 ft)

Vol = 1000 ft^3

7. Calculate the volume (in gallons) of a basin that measures 22 feet by 11 feet by 5 feet deep.

Vol = (22 ft)(11 ft)(5 ft)

Vol = (1210 ft^3)(7.48 gal/ft^3)

Vol = 9050.8 gal

8. Calculate the volume (in gallons) of water in a tank that is 254 feet long, 62 feet wide, and 10 feet deep if the tank only contains 2 feet of water.

Vol = (254 ft)(62 ft)(2 ft)

Vol = (31496 ft^3)(7.48 gal/ft^3)

Vol = 235,590.08 gal

9. Calculate the volume of water in a tank (in gallons) that is 12 feet long by 6 feet wide by 5 feet deep and contains 8 inches of water.

$\frac{8 \text{ in}}{} \Big| \frac{1 \text{ ft}}{12 \text{ in}} = 0.6667 \text{ ft}$

Vol = (12 ft)(6 ft)(0.6667 ft)

Vol = (48 ft^3)(7.48 gal/ft^3)

Vol = 359.04 gal

10. Calculate the maximum volume of water (in gallons) for a kids' swimming pool that measures 6 feet across and can hold 18 inches of water.

$\frac{18 \text{ in}}{} \Big| \frac{1 \text{ ft}}{12 \text{ in}} = 1.5 \text{ ft}$

Vol = (0.785)(6 ft)^2(1.5 ft)

Vol = (42.39 ft^3)(7.48 gal/ft^3)

Vol = 317.1 gal

11. How much water (in gallons) can a barrel hold if it measures 3.5 feet in diameter and can hold water to a depth of 4 feet?

Vol = (0.785)(3.5)(3.5)(4 ft)

Vol = (38.465 ft^3)(7.48 gal/ft^2)

Vol = 287.7 gal

12. A water main has just been laid and needs to be disinfected. The main is 30" in diameter and has a length of 0.25 miles. How many gallons of water will it hold?

$$\frac{30\,in}{} \Big| \frac{1\,ft}{12\,in} = 2.5\,ft \qquad \frac{0.25\,mi}{} \Big| \frac{5280\,ft}{1\,mi} = 1320\,ft$$

$$Vol = (0.785)(2.5ft)(2.5ft)(1320\,ft)$$

$$Vol = (6476.25\,ft^3)(7.48\,gal/ft^3)$$

$$Vol = 48{,}442.35\,gal$$

13. A water main is 10" in diameter and has a length of 5,000 feet. How many million gallons of water will it hold?

$$\frac{10\,in}{} \Big| \frac{1\,ft}{12\,in} = 0.83\,ft$$

$$Vol = (0.785)(0.83ft)(0.83ft)(5000ft)$$

$$Vol = (3270.83\,ft^3)(7.48\,gal/ft^3)$$

$$Vol = \frac{24465.8\,gal}{1{,}000{,}000} = 0.024\,MG$$

14. A 3 million gallon water tank needs to be disinfected. The method you will use requires you to figure 5% of the tank volume. How many gallons will this be?

$$(3{,}000{,}000\,gal)(0.05) = 150{,}000\,gal$$

15. What is 5% of a 1.2 MG tank?

$$(1{,}200{,}000\,gal)(0.05) = 60{,}000\,gal$$

CONVERSIONS

16. How many seconds in 1 minute?

60

17. How many minutes in 1 hour?

60

18. How many hours in 1 day?

24

19. How many minutes in 1 day?

1440

21. The flow through a pipe is 2.4 cfs. What is the flow in gpm?

$(2.4)(7.48)(60) = 1077.12$ gpm

$$\frac{2.4\ ft^3}{sec} \bigg| \frac{7.48\ gal}{ft^3} \bigg| \frac{60\ sec}{min}$$

22. A pump produces 22 gpm. How many cubic feet per hour is that?

$$\frac{(22)(60)}{7.48} = 176.5\ ft^3/hr$$

$$\frac{22\ gal}{min} \bigg| \frac{ft^3}{7.48\ gal} \bigg| \frac{60\ min}{hr} =$$

23. A treatment plant produces a flow of 6.31 MGD. What is the flow in gpm?

$$\frac{(6.31)(1000000)}{1440} = 4381.9\ gal/min$$

$$\frac{6.31\ MG}{day} \bigg| \frac{1000000\ gal}{MG} \bigg| \frac{day}{1440\ min}$$

24. A pump produces 700 gpm. How many MGD will the pump flow?

$$\frac{(700)(1440)}{1000000} = 1.008\ MGD$$

$$\frac{700\ gal}{min} \bigg| \frac{1440\ min}{day} \bigg| \frac{MG}{1000000\ gal}$$

25. A three-eights mile segment of pipeline is to be repaired. How many feet of pipeline is this?

$$3/8 = 0.375\ mi \bigg| \frac{5280\ ft}{mi} = 1980\ ft$$

26. If there is a 2,200 gallon tank full of water, how many pounds of water is in the tank?

$(2200)(8.34) = 18348$ lb

$$2200\ gal \bigg| \frac{8.34\ lb}{gal}$$

Applied Math for Distribution
Flow Conversions

1. Express a flow of 5 cfs in terms of gpm.

$(5)(7.48)(60) = 2244$ gpm

$$\frac{5\,ft^3}{sec}\cdot\frac{7.48\,gal}{ft^3}\cdot\frac{60\,sec}{min}$$

2. What is 38 gps expressed as gpd?

$(38)(60)(1440) = 3{,}283{,}200$ gpd

$$\frac{38\,gal}{sec}\cdot\frac{60\,sec}{min}\cdot\frac{1440\,min}{day}$$

3. Convert a flow of 4,270,000 gpd to cfm.

$$\frac{(4{,}270{,}000)}{(1440)(7.48)} = 396\ ft^3/min$$

$$\frac{4{,}270{,}000\,gal}{day}\cdot\frac{day}{1440\,min}\cdot\frac{ft^3}{7.48\,gal}$$

4. What is 5.6 MGD expressed as cfs? (round to nearest tenth)

$$\frac{(5.6)(1000\,000)}{(1440)(60)(7.48)} = 8.7\ cfs$$

$$\frac{5.6\,MG}{day}\cdot\frac{1000\,000\,gal}{MG}\cdot\frac{day}{1440\,min}\cdot\frac{min}{60\,sec}\cdot\frac{ft^3}{7.48\,gal}$$

5. Express 423,690 cfd as gpm.

$$\frac{(423{,}690)(7.48)}{1440} = 2200.8\ gpm$$

$$\frac{423{,}690\,ft^3}{day}\cdot\frac{7.48\,gal}{ft^3}\cdot\frac{day}{1440\,min}$$

6. Convert 2730 gpm to gpd.

$(2730)(1440) = 3{,}931{,}200$ gpd

$$\frac{2730\,gal}{min}\cdot\frac{1440\,min}{day}$$

Applied Math for Distribution
Flow and Velocity

Velocity

1. A cork is placed in a channel and travels 370 feet in 2 minutes. What is the velocity of the wastewater in the channel, ft/min?

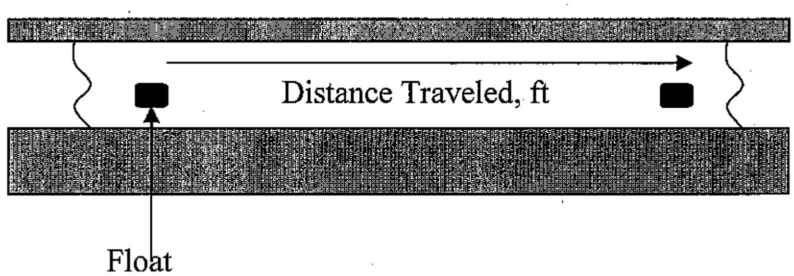
$V = \frac{\text{distance}}{\text{time}}$ $V = \frac{370 \text{ ft}}{2 \text{ min}} = 185 \text{ ft/min}$

2. A float travels 300 feet in a channel in 2 minutes and 14 seconds. What is the velocity in the channel, ft/sec? 2 min 14 sec = 2(60) + 14 = 134 sec

$V = \frac{300 \text{ ft}}{134 \text{ sec}} = 2.2 \text{ ft/sec}$

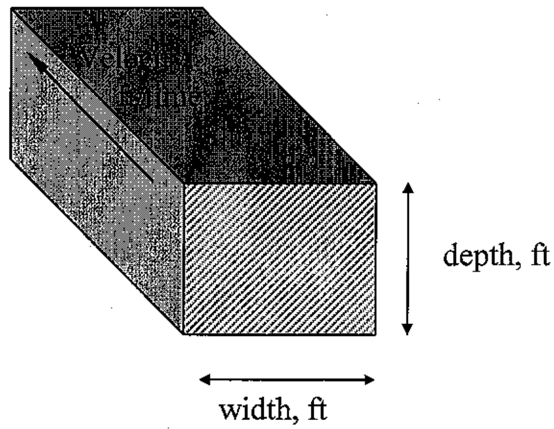
3. The distance between manhole #1 and manhole #2 is 105 feet. A fishing bobber is dropped into manhole #1 and enters manhole #2 in 30 seconds. What is the velocity of the wastewater in the sewer in ft/min? 30 sec = 0.5 min

$V = \frac{105 \text{ ft}}{0.5 \text{ min}} = 210 \text{ ft/min}$



$$\text{Velocity} = \frac{\text{Distance Traveled, ft}}{\text{Duration of Test, min}}$$

$$= \text{ft/min}$$



$$\underset{ft^3/time}{Q} = \underset{(ft)(ft)}{(A)} \quad \underset{(ft/time)}{(V)}$$

A = (width) (depth)

Flow in a channel

4. A channel 48 inches wide has water flowing to a depth of 1.5 feet. If the velocity of the water is 2.8 ft/sec, what is the <u>flow</u> in the channel in <u>cu ft/sec</u>? 48 in = 4 ft

   Q = (4 ft)(1.5 ft)(2.8 ft/sec)

   Q = 16.8 ft³/sec

5. A channel 3 feet wide has water flowing to a depth of 2.5 feet. If the velocity through the channel is 120 feet/min, what is the <u>flow rate</u> in <u>cu ft/min</u>? in <u>MGD</u>?

   Q = (3 ft)(2.5 ft)(120 ft/min)

   Q = 900 ft³/min ⟶ use flow chart to convert

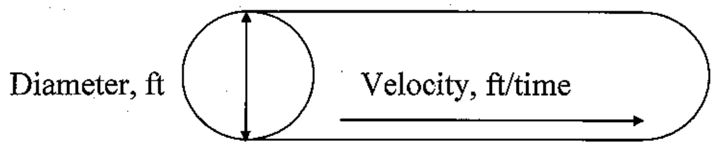
   Q = 9.69 MGD

6. A channel is 3 feet wide and has water flowing at a velocity of 1.5 ft/sec. If the flow through the channel is 8.1 ft^3/sec, what is the <u>depth</u> of the water in the channel in <u>feet</u>?

   $8.1\ ft^3/sec = (3ft)(depth)(1.5\ ft/sec)$

   $\frac{8.1\ ft^3/sec}{(3ft)(1.5\ ft/sec)} = depth$

   $1.8\ ft = depth$



$$\underset{ft^3/time}{Q} = \underset{ft^2}{(A)} \quad \underset{(ft/time)}{(V)}$$

$$\underset{ft^3/time}{Q} = (0.785)\,\underset{(ft)(ft)}{(D)^2}\,\underset{(ft/time)}{(vel)}$$

Flow through a full pipe

7. The flow through a 2 ft diameter pipeline is moving at a velocity of 3.2 ft/sec. What is the flow rate in cu ft/sec?

$Q = (0.785)(2 ft)^2 (3.2 ft/sec)$
$Q = (0.785)(4 ft^2)(3.2 ft/sec)$
$Q = 10.05 ft^3/sec$

8. The flow through a 6 inch diameter pipeline is moving at a velocity of 3 ft/sec. What is the flow rate in ft^3/sec? 6 in = 0.5 ft

$Q = (0.785)(0.5)(0.5)(3 ft/sec)$
$Q = 0.59 ft^3/sec$

9. The flow through a pipe is 0.7 ft^3/sec. If the velocity of the flow is 3.6 ft/sec, and the pipe is flowing full, what is the diameter of the pipe in inches?

$0.7 ft^3/sec = (0.785)(D)^2 (3.6 ft/sec)$
$\frac{0.7 ft^3/sec}{(0.785)(3.6 ft/sec)} = D^2$
$\sqrt{0.2477 ft^2} = \sqrt{D^2} \longrightarrow D = 0.50 ft = 6 in$

10. An 8 inch diameter pipeline has water flowing at a velocity of 3.4 ft/sec. What is the flow rate in gpm?

$\frac{8 in}{} \Big| \frac{1 ft}{12 in} = 0.667 ft$

$Q = (0.785)(0.6667 ft)^2 (3.4 ft/sec)$
$Q = 1.1862 ft^3/sec \longrightarrow$ use flow chart
$Q = 532.4 gal/min$

Section 4

Pretreatment

Pretreatment

Objectives

- Learn the purpose of physical and chemical pretreatment
- Learn the types of physical and chemical pretreatment
- Understand the biological and chemical aspects of pretreatment

Terms

- Adsorption
  - the adhesion of contaminants to an adsorbent such as activated carbon
- Aeration
  - bringing water and air into close contact in order to remove or oxidize unwanted constituents
- Anaerobic
  - absence of air or free oxygen
- Carcinogen
  - chemical compound which could cause cancer

Terms

- Settleability Test
  - a determination of the settleability of solids in suspension by measuring the volume of solids settled out of a volume of sample in a specified time interval
- Short Circuiting
  - when the actual time through a basin is less than the design flow
- Toxic
  - poisonous
- Trihalomethane
  - compound formed when natural organic substances from decaying vegetation and soil reacts with chlorine

Physical Pretreatment

- Removes
  - sticks
  - logs
  - debris
  - algal scum
  - excess sediment
- Reduces loading on treatment plant processes

Chemical Pretreatment

- Adding chemicals to the water before it enters the treatment plant
- Purpose
  - For control of taste and odors
  - To prevent interference with other plant processes

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Physical Pretreatment Processes

- Screening
- Presedimentation
- Microstraining

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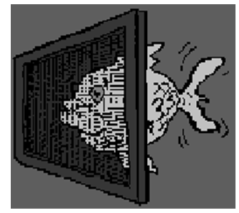
Physical Pretreatment Processes

Screening

- Trash racks
  - Prevent clogging of intake by removing sticks, logs, etc
- Finer screens remove smaller objects



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Physical Pretreatment Processes

Screening

- Screens should be easily removable or have automatic cleaning devices
- Steel or metal screens should be corrosion-resistant or have cathodic protection

9

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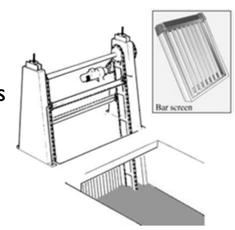
Physical Pretreatment Processes

Bar Screens

- Straight steel bars
- For lakes and streams
- Sloped at an angle of 60-80° to help keep screen from clogging



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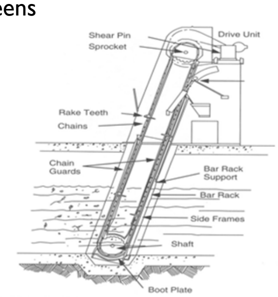
Physical Pretreatment Processes

- Bar Screens



Courtesy of US Filter Envirex Products

FIGURE 3-2 Side view of an automatically cleaned bar screen

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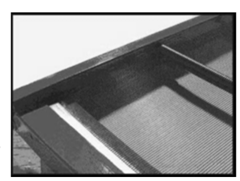
Physical Pretreatment Processes

Wire Mesh Screens

- Woven from stainless steel or corrosion-resistant material
- For streams and lakes with a lot of debris
- Can be lifted out for cleaning or installed with automatic cleaning



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Physical Pretreatment Processes

Maintenance of Screens
- Clogging and corrosion are biggest problem
- All screens must be inspected

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Physical Pretreatment Processes

Inspection of Screens
- Date of inspection
- Amount of material removed
- Unusual debris
- Date and description of repairs

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Physical Pretreatment Processes

Presedimentation
- Removal of silt, sand, and gravel from raw water before it enters the flash mix
  - Surface waters with extensive sediment after rainfall
  - Reduces amount of coagulant needed
  - Reduces potential damage to pumps and other moving parts

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Physical Pretreatment Processes

Presedimentation Systems
- Impoundments
- Sand traps
- Sand and grit removal devices

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Physical Pretreatment Processes

Impoundments
- Basin which allows sediment to settle out before the flash mix
- Benefit
  - stores water for later use
- Problems
  - growth of algae and aquatic plants

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Physical Pretreatment Processes

Mechanical Devices
- Cyclone degritter
  - Uses centrifugal force to remove grit and sand
- Tube settlers
  - Elevated surface on which solids can settle

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Physical Pretreatment Processes

Microstraining

- Removes small debris which could clog filters
- Stainless steel wire fabric
- Rotating drum – algae adheres to fabric
- High-pressure jet causes mat to break away, falls into removal trough

Physical Pretreatment Processes

Microstraining

- Advantages
  - Removes filter-clogging material
  - Decreases chlorine demand
- Disadvantages
  - Does not remove all algae, dissolved solids, bacteria, or viruses
  - Cannot replace any treatment process

Physical Pretreatment Processes

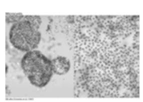
Microstraining

- Chlorine should not be fed before the microstrainer
  - Dead algae are hard to clean off screen
  - Iron can precipitate on screen
  - Chlorine will cause corrosion
  - Chlorine reaction with algae can cause taste and odor problems

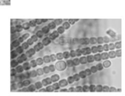
Algae

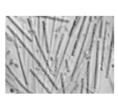
- No true leaves, stems, or roots
- Reproduce by spores, cell division, or fragmentation
- Blue-green, green, diatoms, and flagellates

Algae



- Need sunlight and nutrients to grow
- High levels of nitrogen and phosphorus can cause *algal blooms*
- Some species can produce powerful toxins that damage the liver and nervous system





Algae

Problems Caused by Algae

- Slime accumulation
- Taste, odor and color
- Interference with treatment processes
- Toxicity
- Filter clogging
- Corrosion
- THM precursors

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Algae

Potassium Permanganate

- For control of algae in reservoirs
- Most commonly used to oxidize iron and manganese or taste and odor compounds
- Does not form THMs

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Algae

Powdered Activated Carbon (PAC)

- Physical process of blocking light
- Only practical for small reservoirs
- Can be fed at treatment plant to absorb taste and odor-causing compounds

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Department of Water and Power workers are emptying out bales of plastic balls in the Ivanhoe reservoir in Los Angeles .The Department of Water and Power released about 400,000 black plastic 4-inch balls as the first installment of approximately 3 million to form a floating cover over 7 acres of the reservoir to protect the water from sunlight

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Thermal Stratification

- Formation of layers in a lake or reservoir due to differences in temperature
- 3 zones:
  - Epilimnion - upper, warmer region
    - heated by solar radiation
  - Thermocline - temperature gradient
    - zone of rapid temperature decrease
  - Hypolimnion - lower, colder region
    - no gas exchange with atmosphere

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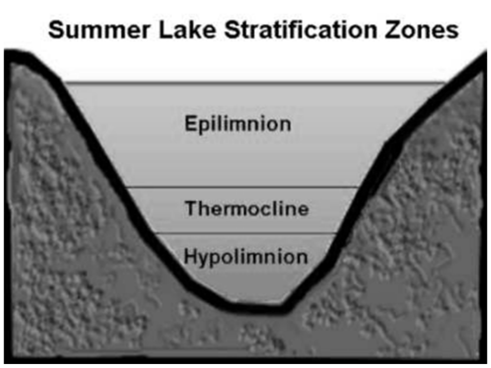

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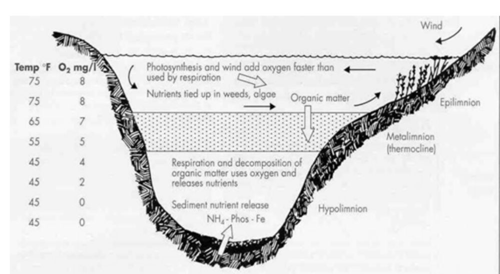

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Thermal Stratification

Water Quality Problems

- Hypolimnion
  - Lower pH
  - Low dissolved oxygen
  - Taste and odor
  - Iron and manganese dissolved
- Epilimnion
  - Algae

Thermal Stratification

Destratification

- Pumping air into hypolimnion to add oxygen and promote mixing of layers
- Prevents stagnation in reservoirs

Zebra Mussels and Clams

- Zebra mussels originated in the Balkans, Poland, and the former Soviet Union
- They first appeared in North America in 1988 in Lake St. Clair, a small water body connecting Lake Huron to Lake Erie
- Biologists believe the zebra mussels were picked up in a freshwater European port in the ballast water of a ship and were later discharged into the Canadian side of Lake St. Clair

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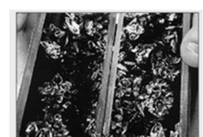
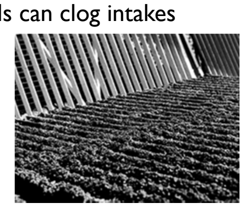
Zebra Mussels and Clams

- Attach to intakes, clog intake screens, reduce flow capacity
- Rapid die-off causes taste & odor problems
- Shells of dead mussels can clog intakes


Zebra mussels (*Dreissena polymorpha*) fouling an intake pipe.
Photo courtesy of Peter Yates.



Zebra Mussels and Clams

- Treatment should begin prior to invasion
- Treatment:
  - Chlorine, potassium permanganate, or copper sulfate applied at intake

Physical Pretreatment Processes

Operation of Presedimentation

- Requires cleaning to prevent buildup and re-suspension of solids
- Deposits can become anaerobic, causing taste and odors

Physical Pretreatment Processes

Record Keeping

- Tells you how often you need to remove sediment
- Tells you what times of the year most sediment is accumulated

Taste and Odor Problems

- Customers judge the quality of their water by its aesthetic properties
  - Mainly taste and odor
- Threshold Odor Number (TON)
- To prevent or treat a problem, you must know the source of the problem

Taste and Odor Problems

Preventative Measures

- Watershed protection and control of nutrients entering water source
- Prevent stagnation
- Physical and chemical pretreatment are an important step in improving the overall efficiency and effectiveness of the treatment process

PRETREATMENT VOCABULARY

______1.	ADSORPTION	______11.	PRETREATMENT
______2.	AERATION	______12.	PRESEDIMENTATION
______3.	ANAEROBIC	______13.	SAND TRAP
______4.	BAR SCREEN	______14.	SCREENING
______5.	CARCINOGEN	______15.	SEDIMENTATION
______6.	TRASH RACK	______16.	SETTLEABILITY TEST
______7.	DIATOM	______17.	SHORT CIRCUITING
______8.	DREDGING	______18.	TOXIC
______9.	MICROSTRAINER	______19.	TRIHALOMETHANE
______10.	PHOTOSYNTHESIS	______20.	WIRE-MESH SCREEN

A. A physical method for controlling aquatic plants in which a dragline or other device is used to remove plants and bottom mud in which they are rooted.
B. Reducing water velocity in basins so that suspended material will settle out by gravity.
C. Compound formed when natural organic substances from decaying vegetation and soil react with chlorine.
D. Process used to remove sand, gravel, and grit from raw water before it enters the actual treatment processes.
E. Involves the adhesion of contaminants to an adsorbent such as activated carbon.
F. Rotating drum lined with a finely woven material used to remove algae and small debris.
G. When the actual flow time through a basin is less than the design flow.
H. Another name for a bar screen. Removes large debris at the intake.
I. The mode by which plants convert solar energy to food.
J. Absence of air or free oxygen.
K. Series of straight steel bars welded at the ends to horizontal steel beams
L. Bringing water and air into close contact in order to remove or oxidize unwanted constituents.
M. Type of algae that contains silica in its cell walls.
N. Any physical, chemical, or mechanical process used before the main water treatment processes.
O. Poisonous.
P. Chemical compound that can cause cancer in animals or humans.
Q. Pretreatment using coarse screens to remove large debris.
R. Wire fabric screen used to remove finer debris from the water than the bar screen is able to remove.
S. A determination of the settleability of solids in a suspension by measuring the volume of solids settled out of a volume of sample in a specified interval of time.
T. An enlargement of a conduit carrying raw water that allows the water velocity to slow down so that sand and other grit can settle.

Pretreatment Review Questions

1. What is the purpose of intake screening?

2. Name two types of screens.
   -
   -

3. What is the purpose of presedimentation?

4. List two examples of chemical pretreatment for algae control.
   -
   -

5. Why should algae not be eliminated from a water source?

6. True or false: Copper sulfate is classified as a pesticide when used to control aquatic organisms in a body of water.

7. The effectiveness of copper sulfate depends mostly on its solubility in water, which depends on what two chemical characteristics?

8. How can watershed management help to control algae and aquatic plants?

9. How can water weeds help to improve the quality of water?

10. How can water weeds degrade the quality of water?

11. What is thermal stratification and why does it occur?

12. What are some water quality problems caused by stratification of a lake or reservoir?

13. Define the terms *oxidation* and *reduction*.

14. What chemicals are commonly used to control zebra mussels?

15. List some problems in water treatment caused by zebra mussels.

Answers to Pretreatment Review Questions:

1. The purpose of intake screening is to remove sticks, debris, algal scum, and excess sediment from water before it is pumped to the treatment plant.

2. Bar screens and wire-mesh screens.

3. Presedimentation removes silt, sand, and gravel; this reduces the amount of coagulant needed and reduces potential damage to pumps and equipment.

4. Copper sulfate and potassium permanganate can be used for algae control.

5. Algae are part of the ecological balance of a lake. Removing it could cause more problems than it would solve.

6. True.

7. Alkalinity and pH affect the solubility of copper sulfate.

8. Watershed management can prevent excess nutrients from entering a lake. Excess nutrients promote the growth of algae and aquatic plants.

9. Water weeds add dissolved oxygen to water and remove nutrients that would otherwise be available for algae.

10. Water weeds provide habitat for problem organisms, cause taste and odor problems.

11. Thermal stratification is the separation of water into layers due to differences in temperature.

12. A lake that is stratified will have low or no oxygen near the bottom, iron and manganese will be dissolved in the lower waters, and turnover will cause poor water quality throughout the lake.

13. Oxidation - chemical reaction involving the addition of oxygen or removal of hydrogen from a substance, making it more stable.
    Reduction - chemical reaction involving the removal of oxygen or addition of hydrogen to a substance. Occurs under anaerobic conditions in a stratified lake.

14. Chlorine gas, potassium permanganate, and copper sulfate have been used to control zebra mussels.

15. Zebra mussels clog intake screens, reducing the pumping capacity. As they die off they create taste and odor problems.

Answers to Pretreatment Vocabulary:

1.	E	8.	A	15.	B
2.	L	9.	F	16.	S
3.	J	10.	I	17.	G
4.	K	11.	N	18.	O
5.	P	12.	D	19.	C
6.	H	13.	T	20.	R
7.	M	14.	Q		

Section 5

Coagulation / Flocculation

COAGULATION/FLOCCULATION

Water Treatment

Objectives

2

- To learn why coagulation and flocculation are important for surface water treatment
- To understand how the coag/floc process works
- To discuss various coagulants and coagulant aids, as well as equipment and methods for feeding coagulants
- To become familiar with regulations concerning coagulation and flocculation
- To learn monitoring and optimizing procedures
- To become familiar with safety procedures

The Need for Coagulation

3

- Particles in water are a result of soil erosion, decay of plant material, industrial contamination, animal wastes, pick up of minerals, etc
- Surface water usually has a lot of suspended and dissolved matter
- These solids must be removed to ensure that the water is safe for consumption
- The coag/floc process facilitates the removal of small, nonsettleable solids

Conventional Treatment

4

- Involves 4 processes:

Coagulation

Flocculation

Sedimentation

Filtration

Effective Process

5

- The effectiveness of the sedimentation and filtration processes depend on the success of the coagulation and flocculation processes
- Disinfection can also be affected by the coagulation and flocculation processes

Process Description

6

- Nonsettleable solids are converted into heavier settleable solids by the addition of a coagulant
- Zeta potential - natural forces which keep particles from sticking together
- Suspended matter is likely to contain microbes which are resistant to chlorine

Nonsettleable Solids

7

- Suspended solids
  - particles held in suspension by velocity of water
- Colloidal solids
  - particles that will not settle within a reasonable amount of time
  - these particles make up turbidity
    - i.e. fine silts, bacteria, color-causing particles and viruses
- Dissolved solids
  - cannot be removed unless precipitated

Natural Forces Between Particles

8

- Zeta potential
  - repelling force between any two particles of like charge
- Van der Waals force
  - attraction between particles pulling them together
- Particles will stay in suspension of zeta potential is greater than the van der Waals force

Coagulation & Flocculation

9

- Coagulation
  - reduces the zeta potential so that van der Waals force can pull particles together to form *microfloc*
- Flocculation
  - brings the microfloc particles together to form larger particles called *macrofloc*

Coagulants

10

- Positively charged chemicals that neutralize negatively charged particles in water to promote coagulation
  - Alum (aluminum sulfate)
  - Ferric Chloride
  - Ferric Sulfate
  - Polyaluminum chlorides

Coagulants

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Alum

- $Al_2(SO_4)_3 \bullet 14\ H_2O$
  - most widely used coagulant
  - available as liquid or dry
- Reacts with alkalinity in water to form $Al(OH)_3$, a jelly- like floc
  - about 0.5 mg/L of alkalinity is required for each mg/L of alum added

Coagulants

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Alum cont'd

- Neutralizes the negatively charged particles of color or turbidity within 1-2 seconds
- Works best in pH range of 5.8 to 8.5 with sufficient alkalinity
  - Liquid alum
    - strong acid
    - pH less than 4
  - Dry alum
    - available in powder, lump form

Coagulants

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Ferric Chloride
- $FeCl_3$
- Highly corrosive
- liquid is 35-45% strength
- will crystallize at 30°F

- Effective over wider pH range than alum, works better in cold water, forms heavier denser floc
- Requires 0.6 mg/L alkalinity for each mg/L ferric chloride
- Reacts with alkalinity in the water to form an insoluble hydroxide $Fe(OH)_3$

Coagulants

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Ferric Sulfate
- $Fe_2(SO_4)$ •3 H_2O or $Fe(SO_4)_3$ •2 H_2O
- Used often with lime softening
- Effective over wider pH range than alum, produces heavier denser flock
- Requires 0.75 mg/L alkalinity for each mg/L ferric sulfate
- Reacts with alkalinity in the water to form an insoluble hydroxide $Fe(OH)_3$

Coagulants

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Polyaluminum Chlorides
- Relatively new to water industry
- Usually require less chemical to achieve coagulation
- Have some characteristics of polymers

Coagulants

16

Alkalinity Concerns
- All coagulants require alkalinity
- If there is insufficient alkalinity, effective floc will not form
- If the alkalinity is increased in the distribution system, the flock may form then, causing sediment buildup and customer complaints

Coagulant Aids

17

- May be added to:
  - Improve coagulation
  - Build stronger, more settleable floc
  - Overcome the effect of temperature drops that slow coagulation
  - Decrease amount of primary coagulant needed
  - Reduces amount of sludge produced

Coagulant Aids

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Polymers
- Have extremely large molecules, that when dissolved in water, produce highly charged ions
- The basic types
  - Cationic (+)
  - Anionic (-)
  - Nonionic

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Coagulant Aids

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Cationic Polymer

- Produce **positively** charged ions when dissolved in water
- Advantages
  - Coagulant can be reduced
  - Floc settles better
  - Less sensitivity to pH
  - Flocculation of bacteria and algae are improved

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Coagulant Aids

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Anionic Polymer

- Produce **negatively** charged ions when dissolved in water
- Advantages
  - Increased floc size
  - Improved settling
  - Strong floc, generally

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Coagulant Aids

21

Nonionic Polymer

- Have a balanced or **neutral** charge
  - They release both positively and negatively charged ions when dissolved
- Less expensive but have higher dosages
  - Cationic and anionic have dosages around 0.1-1.0 mg/L
  - Nonionic dose can range from 1-10 mg/L

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Coagulants : Polymers

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Advantages	Disadvantages
Have little effect on pH	Overfeed can clog filters
May help with very cold water with low turbidity	Spills are very slick, difficult to clean up
Produce less sludge	

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Coagulant Aids

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Weighting Agents

- Add turbidity to highly colored or low turbid water to improve coagulation
- Types
  - bentonite clay
  - powdered silica
  - activated silica
  - powdered limestone

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Coagulation

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pH and Alkalinity Adjustment

- To enhance coagulation , alkalinity may be increased
- Minimum of 10 mg/L alkalinity should be maintained to prevent reformation of floc in distribution system

Coagulation

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pH and Alkalinity Adjustment cont'd

- Increase alkalinity by adding
  - Lime - $Ca(OH)_2$
    - also known as calcium hydroxide, quicklime or hydrated lime
  - Sodium bicarbonate - $NaHCO_3$
  - Soda ash - Na_2CO_3
    - also known as sodium carbonate
  - Caustic soda - NaOH
    - also known as sodium hydroxide

Coagulants

26

Chemical Storage and Handling

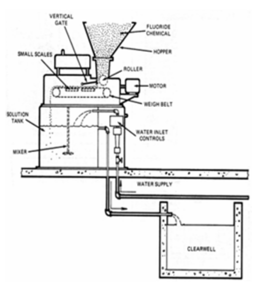
- Dry chemicals should always be kept dry and well ventilated to prevent caking
- Liquid chemicals should be kept from freezing, stored in proper tanks, follow safety precautions when handling
- All storage areas must be kept clean
- Wear protective equipment when handling dry chemicals
  - Dust mask
  - Protective clothing

Chemical Feed Equipment

27

Dry Chemicals Feeders

- Two types:
  - Volumetric
  - Gravimetric
- Chemicals must be in solution before added to the water
  - they require proper agitation

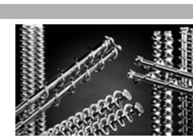


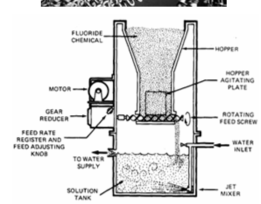
Chemical Feed Equipment

28

Solution Feeders

- liquid pumped from dry tank
- Two types
  - Metering pump
    - positive displacement pump that delivers a precise volume
  - Peristaltic pump
    - roller mechanism pulls chemical through flexible hose





Chemical Feed Equipment

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Flash Mixers

- Provide agitation to evenly mix coagulant through water
- Add chemicals to center of mixing chamber
- Coagulation occurs in less than 1-2 seconds
- This stage determines the success of coagulation
- Detention time should not exceed 30 seconds (Design Criteria)

Chemical Feed Equipment

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Types of Flash Mixers

- Mechanical mixers
- Static mixers
- Pumps and conduits
- Baffled chambers

Chemical Feed Equipment

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Mechanical Mixers

- Placed in a chamber or tank
- Mounted in a pipeline (*in-line mixers*)
- Most reliable and versatile
- Use most energy

Chemical Feed Equipment

32

Static Mixers

- Produce turbulence and mixing through use of fixed sloping vanes
- Effective and economical to install and operate
- High head loss
- Mixing energy directly related to flow with no way to adjust

Chemical Feed Equipment

33

Pumps and Conduits

- Chemicals added to suction side of low-lift pump
- Mixing energy caused by turbulence in pipeline
- Energy determined by speed of pump

Chemical Feed Equipment

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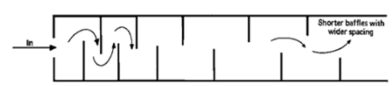
Baffled Chambers

- Mixing occurs as water travels over and under baffles
- Turbulence related to flow, cannot be controlled



Flocculation

35

- Follows coagulation
- Provides gentle agitation to build floc
- Mixing energy must be low so floc will not be sheared
- Floc should not be allowed to settle in floc basin
- DT must be at least 30 minutes, with 45 minutes recommended (Design Criteria)

Flocculation

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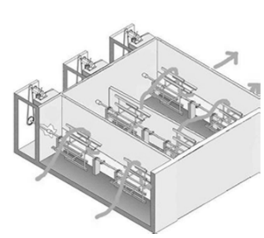

Flocculation Basins

- Can be designed for reduction in velocity gradient as water moves through it
- Must have at least 2 basins
- Velocity should be between 0.5 and 1.5 ft/sec

Flocculation

37

Operation of Process

- Consider water characteristics affecting the selection of chemicals to be used
- Apply chemicals
- Monitor effectiveness

Flocculation

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Operating Factors That Affect Floc Development

- Inadequate flash mixing
- Improper flocculation mixing
- Inadequate flocculation time
- Incorrect chemical dose

Enhanced Coagulation

39

- Adjust process to remove TOC, DBP precursors for compliance with IESWTR (Interim Enhanced Surface Water Treatment Rule)
- Adjust pH for maximum TOC removal
- Iron salts better at removing TOC than other coagulants

Water Characteristics Affecting Chemical Selection

40

turbidity alkalinity
pH
color temperature

- As water quality changes, coagulant effectiveness changes

Water Characteristics Affecting Chemical Selection

41

Turbidity

- Floc doesn’t form well when turbidity is low
- May have to add weighting agent
- Coagulant dose must be raised when turbidity increases
- Don’t lower coagulant dose too soon when turbidity starts to drop

Water Characteristics Affecting Chemical Selection

42

pH

- There is an optimal range for each chemical
- Lime, soda ash, & caustic soda <u>raise</u> pH
- Sulfuric acid <u>lowers</u> pH

Alkalinity

- at least 10 mg/L left over

Water Temperature

- Reactions occur slower in colder water
- Requires more coagulant in cold water

Water Characteristics Affecting Chemical Selection

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Color

- Caused by organics, such as humic acid
- Highly colored water is often low in turbidity
- Usually has low alkalinity
- Color removal is an increasing concern because there seems to be a link between color-causing substances (organics) and THM formation when chlorine is added

Water Characteristics Affecting Chemical Selection

44

Total Organic Carbons (TOC)

- Measured in raw and finished water
- Disinfection By-Product (DBP) precursor

Specific Ultraviolet Absorbance (SUVA)

- Measures UV light at 254 nm and divides that value by the Dissolved Organic Carbon (DOC)
- The SUVA is an indicator of humic content (a DBP precursor)

Choosing a Coagulant

45

- Begin by using the jar test with various chemicals
  - Dose
  - Mixing speed
  - Chemical combination
- Full-scale plant operation may not match jar test results
- Indication of improper flash mixing, coagulant
  - Pinpoint floc
  - High settled turbidity
  - Frequent filter backwash

Control Tests

46

Tests that are used to optimize the coagulation and flocculation processes

- Jar test
  - allows you to test different chemicals or dosages before you try them in your plant
- pH
  - ensures proper pH range for coag/floc process
- Turbidity (settled)
  - success of sedimentation process
- Turbidity (finished)
  - overall process success

Control Tests

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- Zeta potential meter
  - measures charge of water
- Streaming current monitor
  - measures overall charge after coagulant is added
- Particle counter
  - measures size and concentration of particles in finished water

Control Tests

48

- Visual inspection of floc in floc basins
  - size and distribution of floc
- Visual inspection of how floc settles in sedimentation basin
  - little or no carryover into weirs
- Calibrate feeder equipment at least once per shift
- Use in-line monitors to measure water quality

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Operating Problems

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Common Operating Problems

- Low water temperature
  - As temp drops, water becomes more viscous
  - Solutions: operate near optimal pH, increase coagulant dose, add weighting agent or coagulant aid
- Weak floc
  - Passes through filters
- Slow floc formation
  - Often caused by low turbidity or insufficient alkalinity
  - Solutions: add weighting agent or increase alkalinity

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Safety

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- Most dry chemical can irritate eyes, skin and mucous membranes
- Dry chemicals need dust-control equipment and protective clothing such as goggles and a respirator

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Safety

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- Liquid chemicals can be slick, which can be a slip hazard
- Clean up spills immediately

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Safety

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- Dry alum and quick lime can create a lot of heat when mixed together
  - If the temperature reaches 1,100°F (593°C), highly explosive gas can be released
  - These chemicals should be stored separately

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Records

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- Raw water quality and chemical dose should be recorded for future reference
- Can help operators determine proper dose when water quality changes
- Change only one parameter at a time and document the results
- Document everything you try – even if it doesn't work

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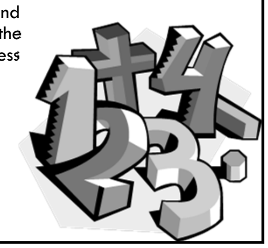
Coagulation and Flocculation

Calculating dosages, conversions, feeder settings, and other calculations relevant to the coagulation/flocculation process



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Calculating Pounds per Day (lb/day)

55

- A water plant treats 5.8 MGD. If the alum dose is 19 mg/L, how many pounds per day of alum will the operator feed?

lbs = (dose, mg/L)(volume, MG)(8.34 lb/gal)

= (19 mg/L)(5.8 MG)(8.34 lb/gal)

= 919 lb/day alum

Calculating Grams per Minute (gpm)

56

- The average flow for a water plant is 12 MGD. Jar tests indicate that the best alum dose is 26 mg/L. What would be the setting in grams/min?

$$\text{gram/min} = \frac{(\text{dose, mg/L})(\text{flow, gpd})(3.785\ \text{L/gal})}{(1440\ \text{min/day})(1000\ \text{mg/gram})}$$

$$= \frac{(26\ \text{mg/L})(12{,}000{,}000\ \text{gpd})(3.785\ \text{L/gal})}{(1440\ \text{min/day})(1000\ \text{mg/gram})}$$

= 820 gram/min

Dosage

57

- A water plant used 12 lbs of polymer to treat 0.5 million gallons of water during a 24-hr period. What is the dosage in mg/L?

$$\text{Dosage, mg/L} = \frac{\text{chemical feed, lbs/day}}{(\text{flow, MGD})(8.34\ \text{lb/day})}$$

$$= \frac{12\ \text{lb/day}}{(0.5\ \text{MGD})(8.34\ \text{lb/day})}$$

= 2.9 mg/L

Dilutions

58

- Liquid polymer is supplied to a water treatment plant as an 8% solution. How many gallons of this would it take to make 55 gallons of 1% solution?

(Conc. 1)(Vol. 1) = (Conc. 2)(Vol. 2)

(0.08)(? gal) = (0.01)(55 gal)

$$? \text{ gal} = \frac{(.01)(55\text{gal})}{.08}$$

gal = 6.9 gal

Liquid Feeder Setting

59

- An operator wants to feed 11 mg/L of alum for a flow of 1.2 MGD. The alum contains 643 milligrams of dry chemical per milliliter of liquid. What would be the setting on the liquid alum feeder?

$$\text{mL/min} = \frac{(\text{dose, mg/L})(\text{flow, gpd})(3.785\text{L/gal})}{(\text{chem conc., mg/mL})(1440\ \text{min/day})}$$

$$= \frac{(11\text{mg/L})(1{,}200{,}000\ \text{gpd})(3.785\text{L/gal})}{(643\text{mg/mL})(1440\ \text{min/day})}$$

= 54 mL/min

Liquid Feeder Setting

60

- A water plant treats 10 MGD with 25 mg/L liquid alum. How many gallons per day will be used? The alum contains 5.35 lbs dry alum per gallon.

$$\text{gal/day} = \frac{(\text{chem dose, mg/L})(Q,\ \text{MGD})(8.34\text{lbs/gal})}{\text{chem conc., lbs./gal}}$$

$$= \frac{(25\ \text{mg/L})(10\ \text{MGD})(8.34\text{lbs/gal})}{5.35\ \text{lbs/gal}}$$

= 390 gal/day

Ferric Chloride

61

- A plant has just switched from alum to ferric chloride. Jar tests indicate that 9.3 mg/L should be fed to treat 5.0 MGD. How many mL/min should be fed if each mL of solution contains 594 mg dry chemical?

$$\text{mL/min} = \frac{(\text{dose, mg/L})(\text{flow, gpd})(3.785\text{L/gal})}{(\text{chem conc., mg/mL})(1440 \text{ min/day})}$$

$$= \frac{(9.3\text{mg/L})(5{,}000{,}000 \text{ gpd})(3.785\text{L/gal})}{(594\text{mg/mL})(1440 \text{ min/day})}$$

$$= 206 \text{ mL/min}$$

Chemical Name and Formula	Common or Trade Name	Shipping Container	Suitable Handling Materials	Available Forms	Weight lb/ft^3	Solubility lb/gal	Commercial Strength percent	Characteristics
Aluminum Sulfate $Al_2(SO_4)_3 \bullet 14\ H_2O$	Alum, filter alum, sulfate of alumina	100-200-lb bags, 300-400-lb bbls, bulk (carloads), tank trucks, tank cars	Dry – iron, steel; solution – lead-lined rubber, silicon, asphalt, 316 stainless steel	Ivory-colored: powder, granule, lump, liquid	38-45 60-63 62-67 10(lb/gal)	4.2 (60°F)	15-22 (Al_2O_3) 8(Al_2O_3)	pH of 1% solution 3.4
Ammonium Aluminum Sulfate $Al_2(SO_4)_3(NH_4)_2SO_4 \bullet 24\ H_2O$	Ammonia alum, crystal alum	Bags, bbls. Bulk	Duriron, lead, rubber, silicon, iron, stoneware	lump, nut, pea, powdered	64-68 62 65 60	0.3 (32°F) 8.3 (212°F)	11(Al_2O_3)	pH of 1% solution 3.5
Bentonite	Colloidal clay, volclay, wilkinite	100-lb bags, bulk	Iron, steel	powder, pellet, mixed sizes	60	Insoluble (colloidal sol used)	-----------	-----------
Ferric Chloride $FeCl_3$ (35-45% solution)	"ferrichlor", chloride of iron	5-, 13-gal carboys, trucks, tank cars	Glass, rubber, stoneware, synthetic resins	Dark brown syrupy liquid	-----------	Complete	37-47($FeCl_3$) 20-21(Fe)	
$FeCl_3 \bullet 6\ H_2O$	Crystal ferric chloride	300-lb bbls	-----------	Yellow-brown lump	-----------	-----------	59-61($FeCl_3$) 20-21(Fe)	Hygroscopic (store lumps and powder in tight container) no dry fee; optimum pH, 4.0-11.0
$FeCl_3$	Anhydrous ferric chloride	500-lb casks; 100-, 300-, 400-lb kegs	-----------	Green-black powder	-----------	-----------	98($FeCl_3$) 34(Fe)	
Ferric Sulfate $Fe_2(SO_4)_3 \bullet 9\ H_2O$	"ferrifloc", ferrisul	100-, 175-lb bags, 400-, 425-lb drums	Ceramics, lead, plastic, rubber, 18-8 stainless steel	Red-brown powder, 70 or granule 72	-----------	Soluble in 2-4 parts cold water	90-94($Fe_2(SO_4)_3$) 25-26 (Fe)	Hygroscopic; cakes in storage, optimum pH 3.5-11.0
Ferrous Sulfate $FeSO_4 \bullet 9\ H_2O$	Copperos, green vitriol	Bags, bbls, bulk	Asphalt, concrete, lead, tin, wood	Green crystal granule, lump	63-66	-----------	55 ($FeSO_4$) 20 (Fe)	Hygroscopic; cakes in storage, optimum pH 8.5-11.0
Potassium Aluminum Sulfate $K_2SO_4 \bullet Al_2(SO_4)_3 \bullet 24H_2O$	Potash Alum	Bags, lead-lined; bulk (carloads)	Lead, lead-lined, rubber, stoneware	Lump, granule, powder	62-67 60-65 60	0.5 (32°F) 1.0 (68°F) 1.4 (68°F)	10-11 (Al_2O_3)	Low, even solubility; pH of 1% solution, 3.5
Sodium Aluminate $Na_2O\ Al_2O_3$	Soda Alum	100-, 500-lb bags, 250-, 440-lb drums, solution	Iron, plastics, rubber, steel	Brown powder, liquide (27°Be)	50-60	3.0 (68°F) 3.3 (86°F)	70-80 ($Na_2Al_2O_4$) min. 32 ($Na_2Al_2O_4$)	Hopper agitation required for dry feed
Sodium Silicate $Na_2O\ SiO_2$	Water Glass	Drums, bulk (tank trucks, tank cars)	Cast iron, rubber, steel	Opaque, viscous liquid	-----------	Complete	38-42°Be	Variable ratio of Na_2O to SiO_2; pH of 1% solution, 12.3

Coagulation / Flocculation Vocabulary

_______1. Activated Silica
_______2. Alum
_______3. Aluminum Sulfate
_______4. Anionic Polyelectrolyte
_______5. Cationic Polyelectrolyte
_______6. Coagulant
_______7. Coagulant Aid
_______8. Coagulation
_______9. Colloidal Solid
_______10. Diaphragm Pump
_______11. Dissolved Solids
_______12. Divalent
_______13. Ferric Sulfate
_______14. Flash Mixing
_______15. Floc
_______16. Flocculation
_______17. Gravimetric Feeder
_______18. Metering Pump
_______19. Microfloc
_______20. Monovalent Ion
_______21. Nonionic Polyelectrolyte
_______22. Nonsettleable Solid
_______23. Polyelectrolyte
_______24. Polymer
_______25. Positive Displacement Pump
_______26. Peristaltic Pump
_______27. Suspended Solid
_______28. Trivalent Ion
_______29. Van der Waals Force
_______30. Viscosity
_______31. Volumetric Feeder
_______32. Weighting Agent
_______33. Zeta Potential

A. A chemical used in water treatment for coagulation.
B. An ion having three valence charges.
C. Forms both positively and negatively charged ions when dissolved in water.
D. Millivolt measurement of the particle charge strength surrounding colloidal solids.
E. Metering pump in which a flexible rubber, plastic or metal diaphragm is used to draw in and discharge a liquid.
F. An ion that has a valence charge of two.
G. Commonly called alum.
H. Finely divided solids, such as bacteria and fine clay particles, that will stay suspended in water for long periods of time.
I. A type of piston, gear, diaphragm, or screw pump that delivers a specific volume of liquid for each stroke.
J. A material, such as bentonite, added to low-turbidity water to provide additional particles for good floc formation.
K. A type of positive displacement pump used to fee chemical solutions by adding a measured volume of solution with each stroke or rotation of the pump.
L. An iron salt used for coagulation.
M. Collections of smaller particles (such as silt, organic matter and microorganisms) that have come together (agglomerated) into larger, more settleable particles as a result of the coagulation/flocculation process.
N. The most common chemical used for coagulation.
O. A pump that uses rollers to squeeze chemicals through a flexible tube.
P. The resistance of a fluid to flowing due to internal molecular forces.

Q. The water treatment process that causes very small-suspended particles to attract one another and form larger particles.
R. Polyelectrolyte that forms positively charged ions when dissolved in water.
S. The initial floc formed immediately after coagulation, composed of small clumps of solids. Pinfloc.
T. A coagulant aid used to forma denser, stronger floc. It is mixed with an acid.
U. The water treatment process, following coagulation, that uses gentle stirring to bring suspended particles together so that they will form larger, more settleable clumps called floc.
V. The attractive force existing between colloidal particles that allow coagulation process to take place.
W. The process of quickly mixing a chemical solution uniformly through the water.
X. High molecular weight, synthetic organic compound that forms ions when dissolved in water. Also called a polymer.
Y. A polyelectrolyte that forms negatively charged ions when dissolved in water.
Z. A chemical added during coagulation to improve the process by stimulating floc formation of by strengthening the floc so it holds together better.
AA. A chemical feeder that adds specific weights of a dry chemical.
BB. Any material that is dissolved in water and can be recovered by evaporating the water after filtering the suspended material.
CC. Solid organic and inorganic particles that are held in suspension by the action of flowing water.
DD. An ion having a valence charge of one.
EE. Common name for polyelectrolytes.
FF. A chemical feeder that adds specific volumes of dry chemicals.
GG. Finely divided solid that will not settle out of water for very long periods of time unless the coagulation/flocculation process is used.

Coagulation Review Questions

1. What are four steps of conventional treatment?
   -
   -
   -
   -

2. What is the difference between van der Waals force and zeta potential?

3. Why is alkalinity required for the coagulation/flocculation process?

4. List three basic types of coagulant aids.
   -
   -
   -

5. What are some advantages of using a coagulant aid?

6. What stage of the coagulation/flocculation process is the most critical?

7. List the recommended detention times for the following, according to the Design Criteria for the State of Tennessee.
   - Flash mix –
   - Flocculation –

8. Define the term “enhanced coagulation”.

9. What is the minimum amount of residual alkalinity recommended for finished water to prevent floc formation in the distribution system?

10. How do the following water characteristics affect the coagulation process?
    - pH –
    - Alkalinity –
    - Temperature –
    - Color –

11. What is the recommended velocity range for flocculation basins?

12. List the three types of nonsettleable solids found in water.

13. Define coagulation.

14. What is flocculation?

15. What are floc particles?

16. List the two most common coagulants used in water treatment.

17. List the physical and chemical factors that affect coagulation.

18. What is the test used to select chemical coagulants and determine the best coagulant dose?

19. List three general types of coagulant aids.

20. In what forms are coagulants and coagulant aids available?

21. List five basic facilities required in the coagulation process.

22. Why are coagulants and coagulant aids sometimes dissolved or diluted before being added to the raw water?

23. List two types of dry chemical feeders. What are the differences between them?

24. What is the most common type of coagulant solution feeder?

25. What are the fundamental steps that are involved in operating the coagulation/flocculation process?

26. List and describe at least three common operating problems associated with the coagulation/flocculation process. What can be done to solve these problems?

27. List the five operational control tests that the operator can use to help operate the coagulation/flocculation process.

28. Discuss some of the hazards associated with the handling of coagulant chemicals.

Answers to Vocabulary

1. T
2. N
3. G
4. Y
5. R
6. A
7. Z
8. Q
9. GG
10. E
11. BB
12. F
13. L
14. W
15. M
16. U
17. AA
18. K
19. S
20. DD
21. C
22. H
23. X
24. EE
25. I
26. O
27. CC
28. B
29. V
30. P
31. FF
32. J
33. D

Answers to Review Questions

2. The four steps of conventional treatment are: coagulation, flocculation, sedimentation and filtration
3. Van der Waals force is the attractive force between particles. Zeta potential is the natural repulsion between particles that keeps them from coagulating.
4. Coagulants work by forming an insoluble precipitate with alkalinity in the water.
5. Three types of coagulant aids are: polymers, weighting agents and activated silica
6. Coagulant aids build a stronger and more settleable floc, they decrease the amount of primary coagulant needed, and reduce the amount of sludge produced.
7. Flash mixing is the most critical stage of the coagulation/flocculation process.
8. Flash mix detention time – should not exceed 30 seconds. Flocculation – 30 minutes minimum, 45 minutes recommended.
9. Enhanced coagulation is the adjustment of coagulant dose and pH for maximum removal of total organic carbon (TOC) to reduce THM’s and disinfection by-products.
10. Finished water should have at least 10-mg/L alkalinity to prevent floc re-formation in the distribution system.
11. Each coagulant has an optimal pH range for coagulation.
    Water must have sufficient alkalinity for coagulants to react with.
    Coagulation takes place quicker, floc forms better in warmer water.
    Color is caused by organics in the water. These do not form floc well. Highly colored water may also have low alkalinity that affects coagulation.
12. Water should move through flocculation basins at a velocity of 0.5 – 1.5 feet per second.
13. Suspended, colloidal, dissolved

14. The neutralization of the electrical charge on the particle followed by the gathering together (agglomeration) of the neutral particles and the chemicals added. Floc is easily settled or filtered.
15. The gentle mixing of the microflocs formed during coagulation to form visible floc particles, which can easily be settled or filtered.
16. Visible particles made up of the original nonsettleable particles and the chemicals added. Floc is easily settled or filtered.
17. Alum and ferric sulfate.
18. Mixing conditions during coagulation and the water pH, alkalinity and temperature.
19. Jar test
20. Cationic, anionic and nonionic
21. Dry and liquid
22. (1) Chemical storage, (2) solution preparation equipment, (3) dosing equipment, (4) flash mixing equipment, and (5) the flocculation basin
23. This gives the operator more precise control over the dosage.
24. Volumetric and gravimetric. Volumetric is less and expensive and less accurate.
25. The chemical metering pump.
26. Selecting the chemicals, applying the chemicals, and monitoring the process effectiveness.
27. Low water temperatures, weak floc, slow floc formation. In all cases, mixing, detention time and choice of coagulant and coagulant aid should be altered as necessary to achieve good coagulation/flocculation.
28. Jar test, pH, turbidity (continuous monitoring), filterability and zeta potential.
29. Some of the hazards associated with handling coagulant chemicals include:
    a. The handling of dry chemicals can create a dust, which is very dangerous if inhaled or allowed on the skin or eyes (especially a problem with lime, soda ash and alum)
    b. Accidental mixing of some chemicals can create tremendous heat and could result in an explosion
    c. Some chemicals, such as alum, can irritate skin, eyes and mucous membranes.
    d. Lump alum can cause cuts.
    e. Polyelectrolytes are slick and spills create dangerously slippery surfaces.

Section 6

Sedimentation

Sedimentation

1

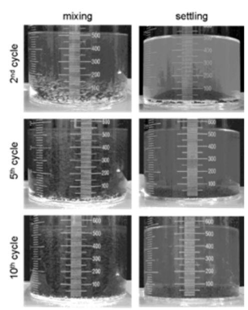
Objectives

- Know the goals of the sedimentation process
- Know the different types of sedimentation processes available
- Know the types and parts of sedimentation basins
- Know sedimentation basin operation
- Know the common operating problems of sedimentation basins

2

Sedimentation

- Sedimentation
  - the settling of suspended solids due to gravity
  - also called *clarification*
- Suspended Solids
  - grit, sand, and chemical precipitates (i.e. iron and manganese) and particles modified by treatment (floc)



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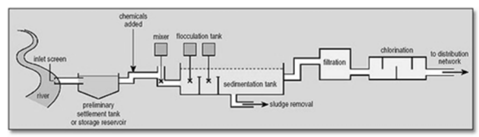
Sedimentation

- Occurs following flocculation and before filtration



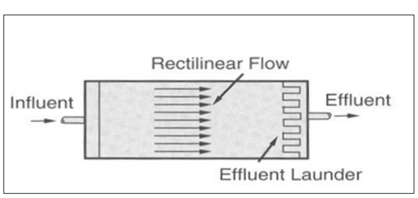
- Decreases the solids loading on filters and other treatment processes
- The decreased loading can result in
  - longer filter runs
  - reduced filter maintenance

4

Types of Sedimentation Basins

1.) Rectangular Basins

- Flow is in one direction
  - parallel to the basin length
  - called *rectilinear flow*
- High tolerance to changing water conditions



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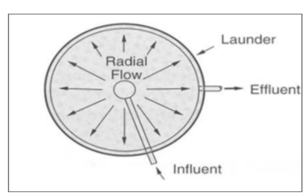
Types of Sedimentation Basins

2.) Circular Basins (center feed)

- Water flows radially from center to outside
  - must keep velocity and flow as even as possible
  - bottom is conical and slopes downward for easier sludge removal



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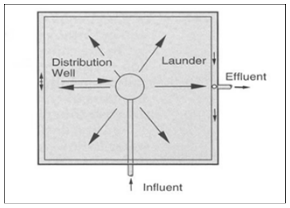
Types of Sedimentation Basins

3.) Square Basins (center feed)
- Flow is from the center to the outside edge
  - must keep velocity and flow as even as possible
  - bottom is conical and slopes downward for sludge removal



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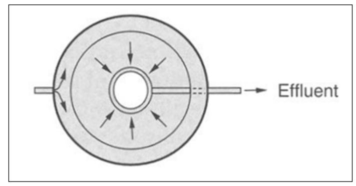
Types of Sedimentation Basins

4.) Circular Basins (peripheral feed with radial flow)
- Flow is from the outside edge (periphery) to the center of the basin
- Design is similar to central feed, radial flow



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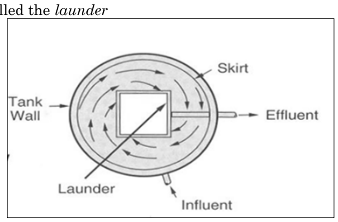
Types of Sedimentation Basins

5.) Circular Basins (peripheral feed with spiral flow)
- Water enters at outside edges
- Flows in a circle around the basin
- Leaves at the center collector
  - called the *launder*



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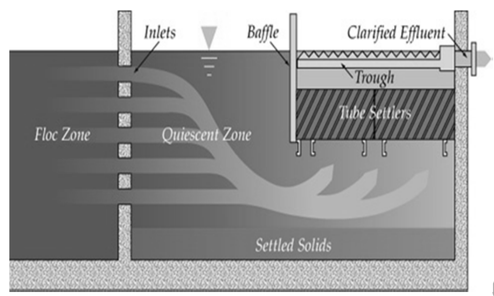
Parts of a Sedimentation Basin



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Parts of a Sedimentation Basin

- Inlet
  - distributes influent water evenly across or around basin
- Baffle
  - installed downstream of inlet to reduce the velocity and produce calm, nonturbulent flow conditions
- Effluent trough (launder)
  - collects settled water and channels it to the effluent pipeline
- Effluent weir (V-notch)
  - part of the effluent launder which distributes the overflow evenly to all points of the launder

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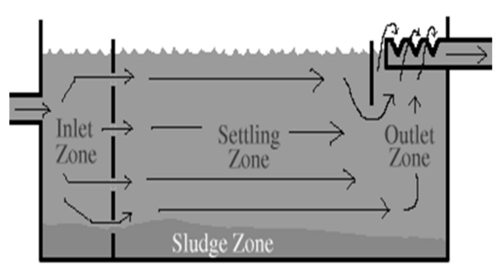
Zones of a Sedimentation Basin



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Zones of a Sedimentation Basin

- Influent Zone (inlet)
  - Decreases the velocity of incoming water from flocculation basin
  - Distributes it evenly across the basin
- Settling Zone
  - Provides the calm area for the suspended material to settle
  - Largest zone
- Effluent Zone
  - Provides smooth transition from settling zone to effluent flow area
  - V-notch weirs enable flow to be evenly distributed
- Sludge Zone
  - Area where solids collect as they settle

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Variations in Sedimentation Process

- Plain Sedimentation
  - Occurs in lakes, reservoirs, or pre-sedimentation basins
  - Reduces heavy sediment loads without chemicals
  - Prevents sediments from
    - damaging pumps
    - creating maintenance problems in the processes which follow

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Variations in Sedimentation Process

- Sedimentation Following Chemical Addition
  - Removes solids which have become larger, heavier, and more settleable due to chemical treatment or conditioning

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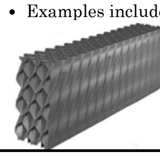
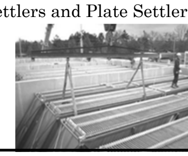
Variations in Sedimentation Process

- Shallow Depth Sedimentation
  - Shallow basins are sometimes used to reduce settling time
  - The principle behind these basins is that surface area is more important than depth
  - For shallow basins to work properly, it is important that coagulant doses and flash mixing be carefully controlled
  - Examples include Tube Settlers and Plate Settlers





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Variations in Sedimentation Process

- Solids-Contact Process
    - Combines coagulation, flocculation, and sedimentation processes into a single treatment unit
  - Usually the basins are circular and contain equipment for mixing, flow circulation, and sludge scraping
  - Coagulation and flocculation take place in the mixing zone
  - Water is "filtered" through sludge blanket and the clarified water flows upward into the effluent troughs
  - A portion of the sludge is recycled to the mixing zone, and the remainder settle to the bottom

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Solids-Contacts Basins

- Also called an *upflow clarifier* or *sludge-blanket clarifier*
- All are divided by baffles into two distinct zones:
  - mixing
  - settling
- Used in lime-soda ash softening, turbidity removal or color removal processes

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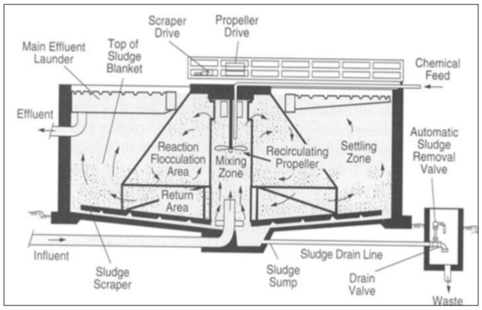
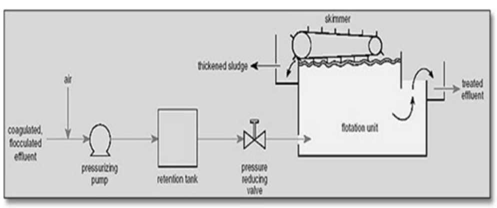
Solids-Contact Basins



Variations in Sedimentation Process

- Dissolved Air Flotation
  - Alternative to sedimentation
  - Gas bubbles carry solid particles to surface
  - Sludge accumulation on top is scraped to disposal trough
  - Must keep pH and alkalinity in proper range for best results
  - Advantages
    - Removes low density particles such as TOC, algae, and *Cryptosporidium oocysts*
    - Can reduce flocculation times to 5-7 minutes

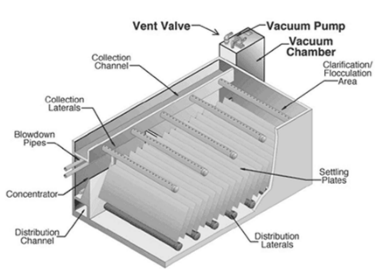
Dissolved Air Flotation



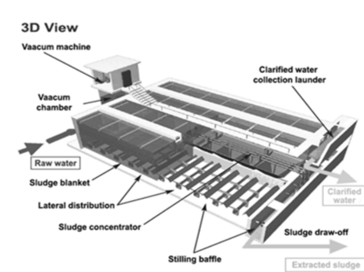
Variations in Sedimentation Process

- Contact Clarifier/Pulsators
  - Simultaneous coagulation and flocculation
  - The sludge from flocculation forms a sludge blanket
  - Coagulated water flows up through the sludge blanket where it is clarified
  - The sludge blanket is maintained at a constant thickness by a vacuum induced pulsation every 40-50 seconds
  - Used to treat highly colored, low turbidity water, in which the formation of settleable floc is usually difficult

Contact Clarifier/Pulsators



Contact Clarifier/Pulsators



Sedimentation Basin Operation

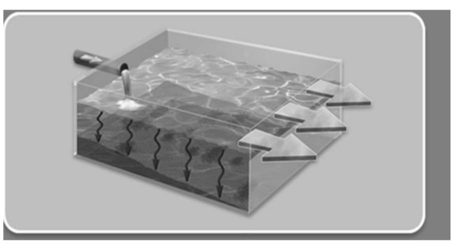
- Goals of Sedimentation
  - To produce settled water with the lowest possible turbidity
  - To reduce the concentration of organics which can cause color or form DBP's (disinfection by products)

Sedimentation Basin Operation

- Factors Affecting Sedimentation
  - Temperature
    - Colder water = slower settling
  - Particle size, shape, and weight
  - Electrical charge of particles
  - Wind and rain
  - Coagulant dose and type
  - Basin hydraulics

Sedimentation Basin Operation

- Factors Affecting Sedimentation
  - A basin's efficiency is determined by the flow rate through the basin



Sedimentation Basin Operation

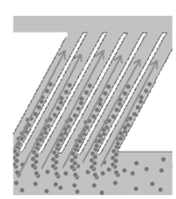
- Detention Time (DT)
  - The theoretical time it takes for a particle of water to pass through the basin
  - Detention time can be shortened due to improper design or short-circuiting
  - Calculated detention time is not always a good estimate of flow
- Detention Times for Various Basins
  - Conventional turbidity removal ---- 4 hours
  - Iron removal ---------------------------- 3 hours
  - Tube settlers ---------------------------- 1 hour

Sedimentation Basin Operation

- Detention Time
  - Weir overflow rates are better indicators of flow
  - Weir overflow rate measured
    - gallon per day of water flowing over each foot of weir
  - At least 2 sedimentation basins are required
  - Total flow should be divided evenly among the basins
  - Flow should be uniform across the length of the weir

Tube Settler Operation

- Due to high loading rates, the floc must have good settling characteristics
- May require coagulant aid or modification of the flocculation process
- Sludge removal required more frequently than in conventional basins



SOLID-CONTACT BASIN OPERATION

- Detention time is short
  - 1-2 hours
- Must have proper coagulation/flocculation and control of solids concentration in sludge blanket
- Solids concentration should be determined twice daily
- Sludge blanket is sensitive to changes in flow, temperature, and turbidity
- Coagulant aids and weighting agents may be required

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PROCESS MONITORING

- Turbidity testing is the best way to monitor if sedimentation process is working

- Jar tests are useful if you experience changes in water quality or change coagulants

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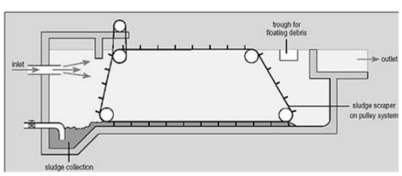
SLUDGE REMOVAL

- Mechanical Removal
  - Rectangular Basins
    - Chain and Flight
      - motor drives chain that pulls flight across basin floor
      - sweeps sludge to end of basin



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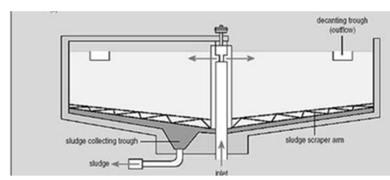
SLUDGE REMOVAL

- Mechanical Removal
  - Traveling Bridge Collector
    - moving bridge scrapes sludge to drain
    - skims scum



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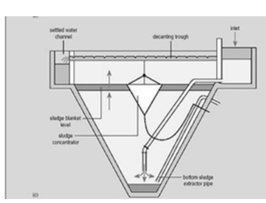
SLUDGE REMOVAL

- Mechanical Removal
  - Floating Bridge Siphon Collector
    - uses suction or submersible pump to withdraw sludge from basin
    - Basin does **not** have to be taken out of service to clean



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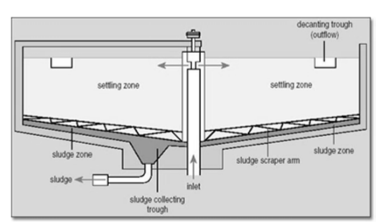
SLUDGE REMOVAL

- Mechanical Removal
  - Circular or Square Basins
    - Scrapers slant downward to center of basin
    - Basin does **not** have to be taken out of service to clean



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Sludge Removal

- Manual Removal
  - Clean basins one or twice a year using fire hose
  - Basin floors usually sloped toward inlet for sludge removal
  - Basin has to be taken out of service to clean
- Sludge Buildup Problems
  - If sludge layer is too thick, solids can be re-suspended
  - Decreases depth of settling basin
  - Reduces detention time
  - Can develop taste & odors from decomposing organic matter

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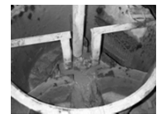
Sludge Disposal

- Raw water quality and coagulant used determine amount of sludge produced
- Alum sludge and ferric sludge are difficult to dewater
- Sludge is pumped to lagoons to dry
  - may take up to a year
- Using a polymer as a coagulant aid can reduce amount of sludge produced



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Sludge Disposal

- If a wastewater plant will accept sludge, it normally doesn't disrupt their process
- Filter backwash water can be combined with sedimentation sludge for disposal
- It is no long advisable to recycle backwash water

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Basin Maintenance

- Drain basins and inspect **at least annually** for proper flow
- Manually cleaned basins should be drained more frequently to wash sludge deposits into the disposal system
- Inspect sludge removal equipment **at least annually**
- Inspect baffles, mixing equipment, etc in solids-contact basins

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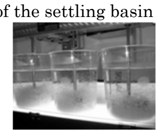
Operating Problems

- Poorly Formed Floc
  - Doesn't settle properly
  - Characterized by smaller loosely held particles that do not settle & are carried out of the settling basin
  - Can be caused by
    - improper mixing
    - dosage
    - type of coagulant
    - changes in raw water
  - Solutions
    - increase mixing energy
    - perform jar tests
    - use coagulant aid



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Operating Problems

- Short Circuiting
  - Water bypasses normal flow and reaches outlet without proper amount of DT
  - Can be caused by
    - poor inlet baffling (main cause)
    - wind driven currents
    - density currents
      - when the influent contains more suspended solids than the water in the basin
      - when the influent is colder than the water in the basin

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Operating Problems

- Short Circuiting
  - Determined by
    - dye test studies
    - fluoride trace studies
  - Circular and square basins have more short circuiting than rectangular
  - Solutions
    - can't be eliminated, should be minimized
    - install additional baffles
    - install protection from wind

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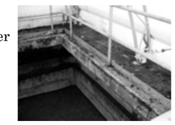
Operating Problems

- Algae and Slime Growth
  - Outdoor, uncovered basins
  - Causes taste and odors
  - Can detach and clog filters or weirs
  - Can create slick, hazardous surfaces
  - Solutions
    - can be controlled with a mixture of copper sulfate and lime or other chemicals
      - drain basin and apply mixture to problem areas with a brush



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Safety

- Open basins require guardrails, life rings or poles
- Sludge and algae create slippery surfaces when cleaning basins
- All machinery with moving parts (i.e. sludge removal) require guards to protect operators

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Regulations

- Sedimentation shall follow flocculation
- The number of basins required is dependent on turbidity, color, colloidal matter and taste & odor causing compounds to be removed
- Minimum detention time (DT)
  - Conventional sedimentation -------- 4 hours
  - Tube settlers ---------------------------- 1 hour
  - Upflow clarifiers ----------------------- 1 hour

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Records

- Records are important for process control when water quality changes
- Keep records on basin maintenance and operation
- Some records may be required for state monthly report forms

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Sedimentation Vocabulary

______1. Baffle
______2. Clarification
______3. Density Current
______4. Detention Time
______5. Dewater
______6. Effluent Launder
______7. Inlet Zone
______8. Jar Test
______9. NTU
______10. Outlet Zone
______11. Overflow Weir
______12. Plain Sedimentation
______13. Radial Flow
______14. Rectilinear Flow
______15. Sedimentation Basin
______16. Settling Zone
______17. Shallow-Depth
______18. Short Circuit
______19. Sludge
______20. Sludge Zone
______21. Solids-Contact Basin
______22. Solids-Contact Process
______23. Surface Overflow Rate (SOR)
______24. Tracer Study
______25. Tube Settlers
______26. Tube-Settling
______27. Turbulence
______28. Weir Overflow Rate (WOR)

A. Location in which water is retained to allow settleable matter, such as floc, to settle by gravity. Also called sedimentation tank, settling tank or settling basin.
B. Removal of a portion of water from sludge.
C. Basin in which coagulation, flocculation and sedimentation processes are combined. Another name for an upflow clarifier.
D. Measurement of number of gallons per day of water flowing over each foot of weir in a settling basin or clarifier.
E. A hydraulic condition in a basin in which the actual flow time of water through the basin is less than the design flow time.
F. The final zone in a sedimentation basin, which provides a smooth transition from the settling zone to the effluent piping.
G. The zone that provides a calm area so the suspended material can settle.
H. The accumulated solids separated from water during treatment.
I. A metal, wooden, or plastic plate installed in a flow of water to slow the water velocity and provide a uniform distribution of flow.
J. Volume of water in a tank divided by the flow rate through the tank.
K. Lab procedure for evaluating coag/floc/sed processes used to estimate the proper coagulant dose.
L. Sedimentation of suspended matter without the use of chemicals or other special means.
M. Uniform flow in a horizontal direction.
N. A series of plastic tubes about 2 in^2 used for shallow-depth sedimentation.
O. The bottom zone of a sedimentation basin, which receives and stores the settled particles.
P. A steel or fiberglass plate designed to evenly distribute flow. In a sed basin, it is attached to the effluent launder.
Q. Measurement of dirt in the water based on the principle of scattered light. Shortened form for expressing Nephelometric Turbidity Units.
R. The initial zone in a sedimentation basin, which decreases the velocity of the incoming water and distributes it evenly across the basin.

S. Any process or combination of processes that reduces the amount of suspended matter in water. Another name for sedimentation.
T. A trough that collects the water flowing from a basin and transports it to the effluent piping system.
U. Direction of flow across a basin from the center to outside edge or vice versa.
V. Study using a substance that can be readily identified in water (such as a dye or fluoride) to determine the distribution and rate of flow in a basin, pipe or channel.
W. A flow of water in which there are constant changes in flow velocity and direction resulting in agitation.
X. A modification of the traditional sedimentation process using inclined tubes or plates to reduce the distance the settling particles have to travel to be removed.
Y. A flow of water that moves through a larger body of water, such as a reservoir or sedimentation basin, and does not become mixed with the other water due to a density difference.
Z. A process combining coagulation, flocculation and sedimentation in one treatment unit, in which the flow of water is vertical.
AA. A shallow-depth sedimentation process that uses a series of inclined tubes.
BB. A measurement of the amount of water leaving a sedimentation basin per square foot of basin surface area.

Sedimentation Review Questions

1. List the four zones into which a sedimentation basin can be divided and name their functions.
   -
   -
   -
   -

2. How do tube settlers increase the efficiency of sedimentation basins?

3. List three problems that can result if sludge is allowed to build up in the sludge zone.
   -
   -
   -

4. What are some advantages and disadvantages of upflow clarifiers?

5. Does sedimentation occur faster or slower when the water temperature is lower?

6. How does the Dissolved-Air Flotation process work?

7. List the minimum detention times for the following:
   - Conventional sedimentation basins –
   - Sedimentation basins for iron removal plants –
   - Sedimentation basins equipped with tube settlers –

8. What is a tracer study?

9. What is the purpose of sedimentation?

10. What are the two basic types of sedimentation and how are they used?

11. What is the flow pattern through a rectangular sedimentation basin? What is the flow pattern through a circular clarifier?

12. Define detention time.

13. What problems are associated with alum sludge? What can be done to reduce these problems?

14. What is short circuiting and what causes it?

15. What is the key operational test to judge performance of the sedimentation process?

Answers to Sedimentation Vocabulary:

1. I
2. S
3. Y
4. J
5. B
6. T
7. R
8. K
9. Q
10. F
11. P
12. L
13. U
14. M
15. A
16. G
17. X
18. E
19. H
20. O
21. C
22. Z
23. BB
24. V
25. N
26. AA
27. W
28. D

Answers to Sedimentation Review Questions:

1. Influent Zone – decreases the velocity of the incoming water and evenly distributes the flow.
   Settling Zone – provides a clam area necessary for the solids to settle.
   Sludge Zone – receives the settled solids and keeps them separate from particles in the settling zone.
   Effluent Zone – provides a smooth transition from the settling zone to the effluent flow area.
2. Each tube acts as a shallow settling basin; as particles come in contact with the tube, it will fall downward due to gravity.
3. If sludge is allowed to build up, it may be resuspended by the velocity of the water, the capacity (detention time) of the basin is reduced, and tastes and odors may develop due to decomposing organic matter.
4. Advantages – takes up less space; three processes in one basin; chemical reactions take place quicker because of recycled sludge; works well for softening
   Disadvantages – require more operator skill and knowledge; coagulant dose must be more accurate; more vulnerable to changes in pH, water quality, temperature
5. Sedimentation occurs slower in lower temperatures.
6. Air is pumped into the bottom of a basin, air bubbles carry solids to the surface, and sludge is scraped off the top.
7. Conventional – 4 hours
   Fe removal – 3 hours
   Tube settlers – 1 hour
8. A tracer study involves tracking the path of water through a basin by using a dye or fluoride. It can determine if short circuiting is occurring.
9. The purpose of sedimentation is to remove settleable solids from the water and reduce loading on the filters and subsequent treatment process.
10. Plain sedimentation removes solids without use of chemicals and is used primarily as a pretreatment process. Sedimentation following chemical addition depends on the use of chemicals to make the solids more settleable. This type is typically used after coagulation/flocculation and before filtration.
11. Rectangular: rectilinear flow; circular: radial flow
12. Detention time is the time it theoretically takes for water to move through the basin. It also can be defined as the time it takes to fill the basin at a given flow rate.
13. Alum sludge is very sticky and difficult to dewater so it can't be disposed of in landfills. Usually a great deal of land is required for lagoons or drying beds and ultimate disposal. Alum sludge can be reduced by making sure over-dosing does not occur and by using coagulant aids so the alum dose can be further reduced.
14. Short circuiting occurs when the water flows through the basin in less than the calculated detention time. It can be caused by poor inlet conditions, density currents and wind.
15. Turbidity is the key operational test. It can be used to determine the effluent quality and the efficiency of the basin by comparing raw-water and effluent quality.

Section 7

Safety

SAFETY

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ACCIDENT

- An accident is caused by either an unsafe act or an unsafe environment

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GENERAL DUTY CLAUSE

Federal – 29 CFR 1903.1

- EMPLOYERS MUST:
  - Furnish a place of employment free of recognized hazards that are causing or are likely to cause death or serious physical harm to employees
  - Comply with occupational safety and health standards promulgated under the Williams-Steiger Occupational Safety and Health Act of 1970.

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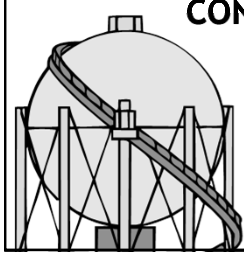
CONFINED SPACES



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CONFINED SPACE CONDITIONS

- Defined as any space where BOTH of the following conditions exist at the same time:
  - existing ventilation is insufficient to remove dangerous air contamination and/or oxygen deficiency which may exist or develop
  - ready access/egress for the removal of a suddenly disabled employee (operator) is difficult due to the location and/or size of opening(s)
- Large enough and so configured that an employee can bodily enter and perform assigned work
- Limited or restricted means of entry or exit
- Not designed for continuous employee occupancy

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CONFINED SPACE EXAMPLES

- Vaults
- Silos
- Inside filters
- Basins
- Storage tanks
- Pits
- Hoppers



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EQUIPMENT NEEDED

- Safety harness with lifeline, tripod, and winch
- Electrochemical sensors
- Ventilation blower with hose

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EQUIPMENT NEEDED cont'd

- PPE
- Ladder
- Rope
- Breathing apparatus

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SPACES THAT REQUIRE PERMITS

- Contains or has potential to contain hazardous atmosphere
- Contains material with potential to engulf and entrant
- Entrant could be trapped or asphyxiated

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ATMOSPHERIC HAZARDS

- Need to have atmosphere monitored!!!
- Explosive or flammable air
- Toxic air
- Depletion or elimination of breathable oxygen

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CHLORINE GAS - Cl_2

- 2.5 times as dense as air
- Liquid expands easily into gas at room temperature 460 times
- Pungent, noxious odor
- Greenish-yellow color
- Toxic by inhalation, ingestion and through skin contact
- May irritate or burn skin

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CHLORINE GAS - Cl_2

- Inhalation can cause serious lung damage and may be fatal
  - 1000 ppm (0.1%) is likely to be fatal after a few deep breaths
    - half that concentration, fatal after a few minutes
- It takes as little as 0.3 ppm to be detected as a distinct odor

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HYDROGEN SULFIDE – H_2S

- Detected by the smell of rotten eggs
- Loss of ability to detect short exposures
- Not noticeable at high concentrations
- Exposures to 0.07% to 0.1% will cause acute poisoning and paralyze the respiratory center of the body
- At the above levels, death and/or rapid loss of consciousness occur

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METHANE GAS – CH_4

- Product of waste decomposition
- Leaks in natural gas pipelines can saturate the soil
- Explosive at a concentration of 5%
- Spaces may contain concentrations above the Lower Explosive Limits (LEL) and still have oxygen above the 19.5% allowable
- Gasoline storage tanks, gas stations, petroleum product pipelines, accidental spills by traffic accidents

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CARBON MONOXIDE - CO

- Decreases amount of oxygen present
- ALWAYS VENTILATE
- 0.15% (1500 ppm) = DEATH
- Will cause headaches at 0.02% in a two hour period
- Maximum amount of 0.04% in 60 minute period
- Colorless, odorless, tasteless, flammable and poisonous

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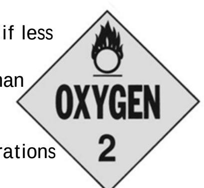
OXYGEN – O_2

- ALWAYS ventilate – normal air contains ~ 21%
- Oxygen deficient atmosphere if less than 19.5%
- Oxygen enriched at greater than 23.5%
  - Speeds combustion
- Leave area if oxygen concentrations approach 22%
- At 8%, you will be dead in 6 minutes
- At 6%, coma in 40 seconds and then you die



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OXYGEN – O_2

- ALWAYS VENTILATE
- Ensure atmosphere contains 21%
- Above 21% can be dangerous
  - Speeds combustion
- Leave area if oxygen concentrations approach 22%
- At 8%, you will be dead in 6 minutes
- At 6%, coma in 40 seconds then you die

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OXYGEN – O_2

- When O_2 levels drop below 16%, a person experiences
  - Rapid fatigue
  - Inability to think clearly
  - Poor coordination
  - Difficulty breathing
  - Ringing in the ears
  - Also, a false sense of well-being may develop

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OXYGEN – O_2

- In a confined space, the amount of oxygen in the atmosphere may be reduced by several factors
  - Oxygen consumption
    - During combustion of flammable substances
    - Welding, heating, cutting or even rust formation
  - Oxygen displacement
    - Carbon dioxide can displace oxygen
  - Bacterial action

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ATMOSPHERIC ALARM UNITS

- Should continuously sample the atmosphere of the area
- Test atmospheres before entering
- Test for oxygen first
- Combustible gases second

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ATMOSPHERIC ALARM UNITS

- Alarms set to read flammable gasses exceeding 10% of the lower explosive limit
  - H_2S exceeds 10 ppm and/or O_2 percentage drops below 19.5%
- Calibrate unit before using
- Most desirable units simultaneously sample, analyze, and alarm all 3 atmospheric conditions

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WRITTEN ENTRY SYSTEM

- Employer shall document entry permits
- Entry supervisor signs permits
- Permit posted
- Shall not exceed time required
- Retain permits for at least 1 year

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INFORMATION ON PERMIT FORMS

- Space to be entered
- Purpose
- Date and authorized duration
- Attendant ID by name
- Authorized entrants ID by name
- Entry supervisor name and signature
- Hazards of permit space
- Measures to eliminate, isolate, or control the hazards
- Results of tests
- Rescue and emergency services
- Communications

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INFORMATION ON EQUIPMENT

- PPE (personal protective equipment)
- Testing equipment

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DUTIES OF ENTRANTS

- Know signs, symptoms, and consequence of exposure
- Properly use equipment
- Alert attendant of warning signs, symptoms and other possible hazards
- Exit when ordered to evacuate by supervisor or attendant

DUTIES OF CONFINED SPACE ATTENDANT

- Know signs, symptoms, and consequences of exposure
- Possible behavioral effects of hazards
- Maintain accurate count of entrants
- Remain outside permit space
- Communicate with entrants
- Summon rescue and emergency units

DUTIES OF CONFINED SPACE ATTENDANT

- Warn unauthorized persons to stay away
- Perform non-entry rescue
- Do not perform any duties that interfere with primary duty of <u>monitoring and protecting entrants</u>

DUTIES OF SUPERVISORS AND MANAGERS

- Knowledge of signs, symptoms, and consequences of exposure
- Verify appropriate entries, procedures, tests and equipment
- Terminate entries and cancel permits if warranted
- Verify means for summoning rescue
- Ensure that acceptable conditions are maintained and operations remain consistent with entry permit

REQUIRED TRAINING

- Employer shall train all employees on hazards, procedures, and skills to perform their jobs safely
- Employees trained before first assigned duty
- Employer shall certify training of employees
- Maintain individual training records of employees

RECORD KEEPING

- Identification and evaluation of all hazardous areas in workplace
- Entrance permits filed
- Training certification
- Written confined space program

GENERAL REQUIREMENTS

- Identify, evaluate, and monitor hazards in permit-required confined spaces
- Post signs "Permit Required"
- Prevent unauthorized entries
- Re-evaluate areas
- Inform contractors
- Have a written program available for employees
- Have proper PPE
- Annual training (OSHA requirement)

CONFINED SPACE REQUIREMENTS

- All electrodes removed and machines disconnected from power sources
- Gas supply shut off
- Gas cylinders outside of work area
- All employees entering must undergo confined space training
- Ventilation used to keep toxic fumes, gasses, and dusts below max levels

LOCKOUT / TAGOUT

LOCKOUT/TAGOUT

General Requirements

- Written program
- Utilize tagout system if energy isolating device not capable of being locked out
- Lockout/tagout hardware provided
- Devices used only for intended purposes
- Tagout shall warn:
  - **DO NOT START. DO NOT ENERGIZE. DO NOT OPERATE.**
- Only trained employees shall perform lockout/tagout

LOCKOUT/TAGOUT

Requirements When Lockout of Equipment

- Notify employees
- Employees notified after completion of work and equipment are re-energized

LOCKOUT/TAGOUT

Recommended Steps for Lockout/Tagout

- Notify employees that device is locked and tagged out
- Turn off machinery normally
- De-activate energy
- Use appropriate lockout/tagout equipment
- Release any stored energy
- Try to start machine by normal means

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LOCKOUT/TAGOUT

Steps for Restoring Equipment

- Check area for equipment or tools
- Notify all employees in the area
- Verify controls are in neutral
- Remove lockout/tagout devices and re-energize device
- Notify employees maintenance and/or repairs are complete and equipment is operational

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LOCKOUT/TAGOUT

Training Requirements

- Employer shall train all employees
- All new employees trained
- Recognition of applicable hazardous energy
- Purpose of program
- Procedures
- Consequences
- ANNUAL REQUIREMENT

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LOCKOUT/TAGOUT

Inspections

- Conduct periodic inspection, at least annually
- Shall include review between the inspector and each authorized employee
- Recommendation
  - Frequent walk-throughs of work areas and observation of Maintenance and Operation area

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LOCKOUT/TAGOUT

Required Record Keeping

- Written lockout/tagout program
- Training
  - Annually and new employees
- Inspections
  - Annual including new equipment, inspection of devices, and procedures

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MOST CITED INDUSTRY STANDARDS BY TOSHA

- No written Hazard Communication Program
- Inadequate Hazard Communication Training
- PPE Hazard Assessment not done
- No Energy Control Program (Lockout/Tagout)
- No MSDS on site
- No one trained in first aid
- No Emergency Action Plan
- Metal parts of cord and plug equipment not grounded
- Unlabeled containers of hazardous chemicals

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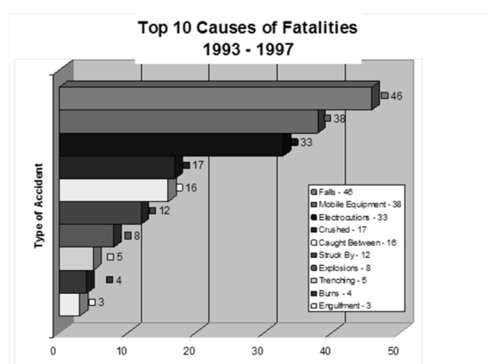

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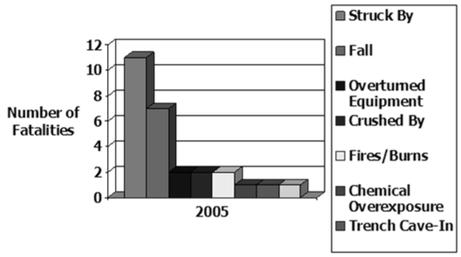
WHAT KILLS IN TN - 2005



Courtesy of TOSHA Winter 2007 Newsletter

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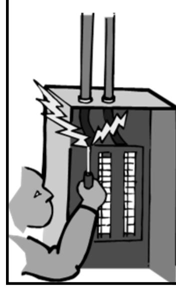
ELECTRICAL SAFETY



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ELECTRICAL SAFETY

OSHA says:

- Any electrical installations shall be done by a professionally trained electrician
- Any employee who is in a work area where there is a danger of electric shock shall be trained
- Employees working on electrical machinery shall be trained in lockout/tagout procedures

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FIRE PROTECTION

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FIRE PROTECTION

Equipment

- Fire extinguishers shall be located where they are readily accessible
- Shall be fully charged and operable at all times
- All fire fighting equipment is to be inspected at least annually

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FIRE PROTECTION

Fire Protection Equipment

- Portable fire extinguishers inspected at least monthly and records kept
- Hydrostatic testing on each extinguisher every five years
- Fire detection systems tested monthly if battery operated

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TYPES OF FIRE EXTINGUISHERS

- Class A
  - Used on combustible materials such as wood, paper or trash
  - Can be water based

- Class B
  - Used in areas where there is a presence of a flammable or combustible liquid
  - Shall not be water based
  - Example is dry chemical extinguisher
  - An existing system can be used but not refilled

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TYPES OF FIRE EXTINGUISHERS

- Class C
  - Use for areas electrical
  - Best is carbon dioxide extinguisher
  - Using water to extinguish a class C fire risks electrical shock
- Class D
  - Used in areas with combustible metal hazards
  - Dry powder type
  - Use no other type for this fire

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FIRE EXTINGUISHERS

Types of Fire Extinguishers

Class	Material	Method
A	Wood, paper	Water
B	Flammable liquids (oil, grease, paint)	Carbon dioxide, foam, dry chemical, Halon
C	Live electricity	Carbon dioxide, dry chemical, Halon
D	Metals	Carbon dioxide

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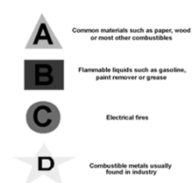
TYPES OF FIRE EXTINGUISHERS

- Combination ABC are most common
- Have the types of extinguishers available depending upon analyses performed in each area



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CHEMICAL SAFETY

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PERSONAL PROTECTIVE EQUIPMENT (PPE)

- Gloves
- Coveralls/overalls
- Face shield/goggles
- Respirator/SCBA
- Boots
- Ear plugs/muffs

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NFPA

- National Fire Protection Association
- Chemical hazard label
  - Color coded
  - Numerical system
    - Health
    - Flammability
    - Reactivity
  - Special precautions
- Labels are required on all chemicals in the lab

RTK LABELS

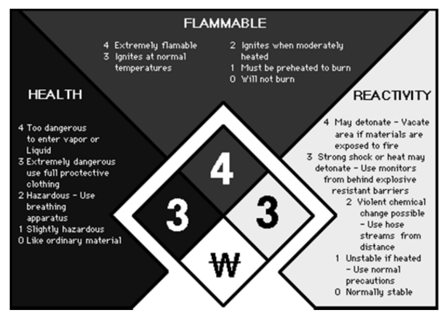
- "Right to Know"
  - In 1983, OSHA instituted Hazard Communication Standard 1910-1200, a rule that gives employees the right to know the hazards of chemicals to which they may be exposed in the workplace.

CHEMICAL HAZARD LABEL

Degrees of Hazard

- Each of the colored areas has a number in it regarding the degree of hazard
  - 4 → extreme
  - 3 → serious
  - 2 → moderate
  - 1 → slight
  - 0 → minimal

CHEMICAL HAZARD LABEL



CHEMICAL HAZARD LABEL

Health

- 4 (extreme)→highly toxic material
  - Very short exposure can cause death or major residual injury even with prompt medical treatment
  - A known/suspected carcinogen, mutagen, or teratogen
- 3 (serious) → toxic material
  - Short term exposure may cause serious temporary or residual injury even with prompt medical treatment
  - A know/suspected small animal carcinogen, mutagen, or teratogen

CHEMICAL HAZARD LABEL

Health

- 2 (moderate) → moderately toxic material
  - Intense or continued exposure could cause temporary incapacitation or possible residual injury even with prompt medical treatment
- 1 (slight) → slightly toxic material
  - May cause irritation by only minor residual injury even without treatment
  - Recognized innocuous material when used with responsible care
- 0 (minimal) → no chemical is without some degree of toxicity

CHEMICAL HAZARD LABEL

Flammability

- 4 (extreme) → extremely flammable
  - Flashpoint below 73ºF
- 3 (serious) → flammable
  - Vaporizes readily and can be ignited under almost all ambient conditions
  - May form explosive mixtures with or burn rapidly in air
  - May burn rapidly due to self-contained oxygen
  - May ignite spontaneously in air
  - Flash point at or above 73ºF but less than 100ºF

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CHEMICAL HAZARD LABEL

Flammability

- 2 (moderate) → combustible
  - Must be moderately heated or exposed to relatively high temps for ignition to occur
  - Solids which readily give off flammable vapors
  - Flash point at or above 100ºF but less than 200ºF
- 1 (slight) → slightly combustible
  - Must be preheated for ignition to occur
  - Will burn in air when exposed at 1500ºF for 5 min
  - Flash point at or above 200ºF
- 0 (minimal)
  - Will not burn
  - Will not exhibit a flash point
  - Will not burn in air when exposed at 1500ºF for 5 min

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CHEMICAL HAZARD LABEL

Reactivity

- 4 (extreme)
  - Can explode or decompose violently at normal temperature and pressure
  - Can undergo a violent self-accelerating exothermic reaction with common materials or by itself
  - May be sensitive to mechanical or local thermal shock at normal temperature and pressure

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CHEMICAL HAZARD LABEL

Reactivity

- 3 (serious)
  - Can detonate or explode but requires a strong initiating force or confined heating before initiation
  - Readily promotes oxidation with combustible materials and may cause fires
  - Sensitive to thermal or mechanical shock at elevated temp
  - May react explosively with water without requiring heat or confinement

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CHEMICAL HAZARD LABEL

Reactivity

- 2 (moderate)
  - Normally unstable and readily undergoes violent change but does not detonate
  - May undergo chemical change with rapid release of energy at normal temp and pressure
  - May react violently with water
  - Forms potentially explosive mixtures with water
- 1 (slight)
  - Normally stable material which can become unstable at high temperature and pressure
- 0 (minimal)
  - Normally stable material which is not reactive with water

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CHEMICAL HAZARD LABEL

Special

- W → water reactive
- Ox → oxidizing agent

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MATERIAL SAFETY DATA SHEETS

- Also called MSDS
- Lists:
  - Common and chemical name
  - Manufacturer info
  - Hazardous ingredients
  - Health hazard data
  - Physical data
  - Fire and explosive data
  - Spill or leak procedures
  - PPE
  - Special precautions

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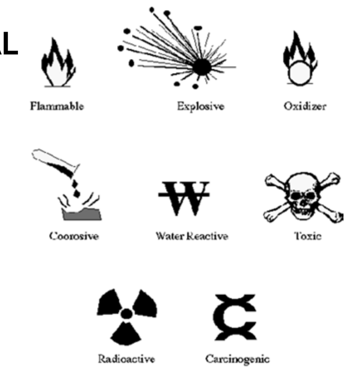
SPECIAL



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SAFETY DATA SHEET

- OSHA moving from HCS (Hazard Communication Standard) to GHS (Globally Harmonized System)
- Revised criteria for chemical hazard classification, labeling & new format for Safety Data Sheets (SDS)
- Final rule effective May 25, 2012 but compliance dates are phased in:
  - Complete training on new label formats: 12/1/13
  - Comply with label and SDS requirements: 6/1/15
  - Update Hazcom programs: 6/1/16

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MSDS TO SDS

- What is the difference between a MSDS and the new SDS?
- SDSs are in use globally
- The Safety Data Sheets (formerly MSDSs) will now have a specified 16-section format

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MINIMUM INFO FOR SDS

- Product identification
- Hazard Identification
- Composition/info on ingredients
- First-aid measures
- Fire-fighting measures
- Accidental release measures
- Handling and storage
- Exposure controls
- Physical/chemical properties
- Stability & reactivity
- Toxicological information
- Ecological information*
- Disposal considerations*
- Transport information*
- Regulatory information*
- Other information (including date of SDS or last revision)*

* Non mandatory

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MSDS TO SDS

- In addition, chemical manufacturers and importers will be required to provide a label that includes a harmonized signal word, pictogram, and hazard statement for each hazard class and category
  - The use of pictograms will enable workers, employers, and chemical users worldwide to understand the most basic chemical information without language barriers

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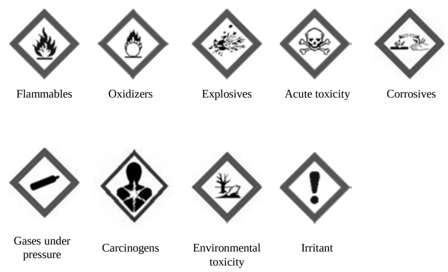
OSHA PICTOGRAMS



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TERMS

- Lower Explosive Level (LEL)
  - minimum concentration of flammable gas or vapor in air that supports combustion
- Upper Explosive Level (UEL)
  - maximum concentration of flammable gas or vapor in air that will support combustion
- Teratogen
  - causes structural abnormality following fetal exposure during pregnancy
- Mutagen
  - capable of altering a cell's genetic makeup

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CHLORINE SAFETY

Hazards of Chlorine Gas

- 2.5 times as dense as air
- Irritating to eyes, nasal passages, respiratory tract
- Lethal concentration = 0.1% or 1,000 mg/L by volume
- Extremely corrosive in presence of water
- Inhalation can cause serious lung damage and may be fatal
- It takes as little as 0.3 ppm to be detected as a distinct odor

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CHLORINE SAFETY

Safety Precautions for Chlorine Gas

- Compressed air
  - 30 minute capacity
- Annually inspected
- Trained/fit tested
- PPE
  - Rubber gloves
  - Apron
  - Goggles
  - Safety shower, eyewash

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CHLORINE SAFETY

Where Chlorine Gas Is Used:

- Separate room for chlorine, with window to view inside
- Ventilation provided for one complete air change per minute
- Air outlet located near the floor
- Air inlet near the ceiling
- Temperature controlled room, 60ºF
- Switches for lights and fans located outside of room, crash-bar on door inside of chlorine room
- Vents from feeders and storage shall discharge to the outside atmosphere, above grade

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CHLORINE SAFETY

Where Chlorine Gas Is Used (cont'd):

- Must have a chlorine gas detection device connected to an alarm that can be heard throughout the treatment plant
- All gaseous feed chlorine installations shall be equipped with appropriate leak repair kits
- A fusible plug, designed to melt at 158º to 165ºF, is located in the valve on a 150-lb cylinder and on the head of a ton container
  - It is designed to relieve pressure in the cylinder or container when exposed to high heat
- Leak detection – an ammonia solution produces white "smoke" in the presence of chlorine
  - A sensor type leak detector is the best means of detecting small leaks, less than 1ppm

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CHLORINE SAFETY

Calcium Hypochlorite (HTH)

- Dry, white or yellow granular material
- Strong oxidizer
- Reacts with organics and can start fires
- Gives off lots of heat when mixed with water
- Will give off chlorine gas when it reacts
- Always add HTH to water when mixing
  - **NEVER add water to HTH!!**

CHLORINE SAFETY

Calcium Hypochlorite (HTH)

- Granular HTH is safer to work with than tablet or liquid form
- HTH should be stored in a cool dry place away from acids, reducing agents, paints, oils, and grease
- Use a carbon dioxide extinguisher to put out fires started by HTH

CHLORINE SAFETY

Calcium Hypochlorite (HTH)

- If a small amount of calcium hypochlorite is spilled, the chemical should be disposed of by dissolving it in a large amount of water

CHLORINE SAFETY

Calcium Hypochlorite (HTH) – PPE

- Eye protection, protective clothing
- Rubber gloves
  - It will react with leather
- Rubber boots
  - It will react with leather
- SCBA

Safety Quiz

Lockout / Tagout

True or False

1. The term "lockout" means to block the flow of energy to equipment and keep it blocked by placing a lock to prevent accidental start-up.
True False

2. The term "tagout" means to place a tag on the power source to identify yourself and the purpose of the lockout, and to warn others not to turn the power back on.
True False

3. If someone else has already applied a lock and tag to a piece of machinery you need to work on, you should not add another one.
True False

4. After locking and tagging out the equipment, you should test the equipment to make sure it won't start.
True False

5. You don't need to use the lockout / tagout procedure if a machine has a built-in safety shut-off.
True False

Confined Spaces

Fill in the blank:

6. A ____________________ is a form designed to make sure workers can safely enter a confined space by establishing procedures that must be followed.

7. The acceptable range for oxygen level in a confined space is _________ %.

8. List some activities that can reduce the level of oxygen in a confined space:

   ____

9. Entry-level permits should be kept on file for at least _________ year(s).

Multiple Choice

10. Which of these are examples of confined spaces? (Circle all that apply)
    a) Storage tanks
    b) Automobiles
    c) Meter pits
    d) Manholes
    e) Meeting rooms

11. When must the atmosphere of a confined space be tested?
    a) Only before a worker enters
    b) Never, if adequate ventilation exists
    c) Continuously
    d) Only if welding or painting is being performed

12. Some gases in a confined space can be:
    a) Colorless
    b) Odorless
    c) Deadly
    d) All of the above

True or False

13. If dangerous conditions exist, you do not have to wait for trained rescue personnel to perform a rescue.

    True False

14. Carbon monoxide and hydrogen sulfide are two common dangerous gases found in confined spaces.

    True False

Calcium Hypochlorite

Multiple Choice

15. Calcium hypochlorite:
    a) Is an oxidizer
    b) May cause a fire if contaminated
    c) Can release hazardous chlorine gas if stored improperly
    d) All of the above

16. Which form of calcium hypochlorite is the safest?
    a) Granular
    b) Tablet
    c) Liquid

17. Calcium hypochlorite should be stored away from:
    a) Acids
    b) Paint
    c) Reducing agents
    d) Oils and greases
    e) All of the above

18. What should be used to extinguish a fire involving calcium hypochlorite?
    a) Water
    b) Carbon dioxide
    c) Chemical smothering agents
    d) All of the above

19. When cleaning up a small spill, you should dispose of the calcium hypochlorite by:
    a) Burying it
    b) Placing it in the trash can
    c) Putting it back in the container
    d) Neutralizing it with acid or ammonia
    e) Dissolving it in a large amount of water

Fill in the blank

20. What personal protective equipment should you wear when handling calcium hypochlorite?

    ____

21. Why should smoking be prohibited in calcium hypochlorite storage areas?

    ____

22. Why must you never dispose of calcium hypochlorite in the trashcan?

    ____

Answers:
1. True
2. True
3. False
4. True
5. False
6. Confined space permit
7. 19.5% - 23.5%
8. Poor ventilation, welding, absorption, chemical consumption
9. One
10. A and D
11. C
12. D
13. False
14. True
15. D
16. A
17. E
18. B
19. E
20. Wear self-contained breathing apparatus and protective clothing to prevent contact with skin and eyes (rubber gloves and rubber boots)
21. Fire hazard
22. Can react with organic material and cause a flash fire

TOSHA Standards Requiring Annual Training

Class	Regulation	Who should attend?
Medical & Exposure Records	1910.20(g)(1)	All employees (inform- existence, person responsible, location, right of access
Emergency Action	1910.38(a)(5) 1910.38(b)(4)	All employees – based upon other standards and requirements
Noise	1910.95(k)	All employees exposed to an 8 hour TWA or greater of 85dBA
Emergency Response	1910.120(q)	Employees who respond to spills of hazardous chemicals
Personal Protective Equipment	1910.132(f)	Employees who wear PPE
Permit-Required Confined Space	1910.146(g)	Employees who enter, attend or supervise P.R. confined spaces
Lock-Out/Tag-Out	1910.147(c)(7)	Employees who work on machinery
First Aid	1910.151(b)	At least one employee on each shift, annual as required by other standards
Fire Brigade	1910.156(c)	All fire brigade members (quarterly and annually)
Portable Fire Extinguishers	1910.157(g)	All employees expected to use fire extinguishers
Fork Lift Trucks	1910.178(1)	Fork lift truck operators
Mechanical Power Presses	1910.217(f)(2)	Operators
Asbestos	1910.1001(j)(1)	All employees exposures at or above PEL or excursion limit
Lead	1910.1025(1)	Anyone with a potential for exposure at any level – copy of appendix A&B. If exposed at or above action level, must be trained
Bloodborne Pathogens	1910.1030(g)(2)	Employees who render first aid
Hazard Communication	1910.1200(h) TDL 800-1-9-.07	Employees exposed or potentially exposed to any type of chemicals
Hazardous Chemicals in Laboratories	1910.1450(f)(2)	Employees exposed to chemicals

Section 8

Lab

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Laboratory Practices

1

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Water Quality

- Process control monitoring
  - All public water systems that provide some type of treatment must monitor water quality
- Monitored to ensure safety and integrity
- Monitored to meet state and federal requirements
- Monitor raw, finished, and where you expect a physical/chemical change in your plant
- Monitor in distribution system also
  - Quality can degrade due to contamination or growth of organisms

2

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Water Quality

Degradation

- Treated water is disinfected, not sterilized
- Disinfection kills or inactivates harmful organisms (pathogens)
- Organisms can grow in distribution system if conditions are right
- To prevent growth of organisms
  - Keep chlorine residuals up
  - Keep excess nutrients out
  - Prevent stagnation
  - Prevent cross-connections

3

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Water Quality

Analysis

- The first step in water quality analysis is collecting samples which accurately represent the water
  - Representative sample
    - sample which contains basically the same constituents as the body of water from which it was taken
  - Improper sampling is one of the most common causes of error in water quality
- All chemical analysis must be kept for <u>10 years</u>

4

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Sampling

Types of Samples

- Grab sample
  - Single volume of water
  - Representative of water quality at exact time and place of sampling
  - Coliform bacteria, residual chlorine, temperature, pH, dissolved gases
- Composite samples
  - Representative of average water quality of location over a period of time
  - Series of grab samples mixed together
  - Determines average concentration
  - Not suitable for all tests

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Sampling

Sample Volume and Storage

- Volume depends on test requirements
- Use proper sampling container
- Follow recommended holding times and preservation methods
  - If bottle already has preservative or dechlorinator in it, don't over fill or rinse out

❖ If you have questions regarding volume, container or holding times, check *Standard Methods* or contact the lab if you have an outside lab do you analysis

6

Sampling

Sample Labeling

- Specific location (address)
- Date and time sampled
- Chlorine residual
- pH and temperature
- Sample type
- Name or initials of person taking sample

7

Sampling

Sample Type

- D – distribution
- R – repeat
  - S – same
  - A – upstream
  - B - downstream
- F – fixed/repaired line in service
- N – new line NOT in service
- S – special sample

8

Sampling

Sample Labeling

Site 196 E. Main Street Billieville, TN

Date / Time August 15, 2005 8:15 AM

Sampled by Billy Joe Smith

Comments grab sample, [illegible] Bac't

pH [illegible] °C

9

9

Sampling

Selecting Sampling Points

- Raw-water supply
- Treatment plant
- Distribution system

10

Sampling

Raw-water Sampling Points

- Install valve or sample cock on raw-water transmission lines or well discharge pipe

11

Sampling

Treatment Plant Sampling Points

- Sampling from various points helps determine efficiency of processes
- Sample at every point where a change in water quality is expected
- Finished water sample point usually at point of discharge from clearwell

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Sampling

Distribution Sampling Points

- Distribution sampling is the best indicator of system water quality
- Water quality changes in the distribution system:
  - Corrosion
    - increase in color, turbidity, taste and odor
  - Microbiological growth
    - slime
  - Cross-connections

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Sampling

Distribution Samples

- Determine water quality at customers' taps
- Most common tests are chlorine residual and coliform bacteria
- Number of samples depends on size of system of water source

14

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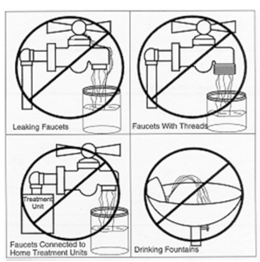
Sampling

Monthly Distribution System Bacteriological Samples

- Samples should never be taken from a hydrant or hose
- Only collect samples from approved faucets
- Don't collect samples from swivel faucets
- Only use cold water tap
- Front yard faucets on homes with short service lines



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Sampling

Monthly Distribution System Bacteriological Samples

- Do not flame faucet with torch
  - Use alcohol or bleach solution to clean
- Turn on faucet to steady flow and flush service line (2-5 min) – getting water from the main line
- Fill bottle to proper level
- Label bottle with pertinent information
- Refrigerate to proper temperature, 4°C
- Test as soon as possible – within 30 hours

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Collection of Samples

- Only approved containers should be used
  - 125 mL volume
  - Pre-sterilized bottles recommended
  - Other bottles sterilized at 121°C for 15 min
  - Should contain sodium thiosulfate

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Collection of Samples

- Remove aerator or screen
- Collect sample from cold water tap
- Sample from homes with short service lines
  - same side of street as water main

18

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Collection of Samples

- Disinfect faucet with sodium hypochlorite
- Flush service line
- Adjust flow so that no splashing will occur

19

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Collection of Samples

- Do not touch inside of lid of sample bottle
- Do not set lid down or put it in your pocket
- Do not rinse bottle or allow it to overflow

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Microbiological Indicator Organism

- Always present in contaminated water
- Always absent when no contamination
- Survives longer in water than other pathogens
- Is easily identified
- Water treatment indicator organism
  - coliform group (total coliforms)

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EPA Approved Methods

- Multiple-Tube Fermentation
- Presence-Absence Test
- MMO-MUG
- Membrane Filter Method
- Enzyme (chromogenic/fluorogenic) Substrate Tests

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Bacteriological Samples

- The MCL for coliform bacteria is based on presence or absence
- Finished and distributed water should be Zero (absent)
- Must keep results for 5 years

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State Regulations

- 1200-5-1.06(4) Microbiological
  - (a)1. If you collect 40 samples/month, no more than 5% can be positive to be in compliance
  - (a)2. If you collect less than 40 samples/month, no more than 1 sample can be positive to be in compliance
  - (c) If any routine or repeat sample test (+) for total coliform, it must be analyzed for fecal or *E. coli*

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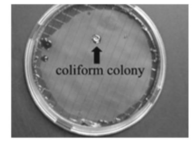
State Regulations

- 1200-5-1.07(2) Repeat Monitoring
  - (a) If a routine sample is total coliform positive, the system must collect a set of repeat samples within 24 hours of being notified of the positive result
  - (b) The system must collect one at original site, at least one repeat within five service connections upstream and at least one repeat within five service connections downstream

Testing



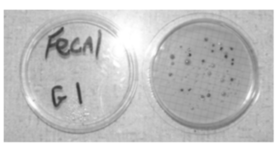
Membrane Filter Technique

- 100 mL sample is filtered through a membrane filter under a vacuum
- Filter placed on sterile Petri-dish containing M-Endo broth (food source for bacteria) for Total Coliforms
- Petri-dish labeled, turned upside down, placed in incubator at 35° +/- 0.5°C for 24 hours
- A coliform bacteria colony will grow at each point on filter where a viable bacterium was left during filtering
- The colonies will appear red with a green-gold metallic sheen

Testing

Fecal Coliform Determination

- Membrane filtration test
- More reliably indicates the potential presence of pathogenic organisms
- Same procedure as Total Coliform, 100 mL sample is filtered through a membrane filter under a vacuum
- Filter placed on sterile Petri-dish containing mFC broth
- Incubation at 44.50 +/- 0.2°C for 24 hrs
- Bacterial colonies appear blue
- Looks for heat tolerant bacteria



Testing

Enzyme Substrate Testing

- Colilert (P/A)
- Colilert Quanti-Tray
- Colilert-18 (P/A)
- Colilert-18 Quanti-Tray
- E*Colite
- Colisure
- Readycult® Coliforms 100 (P/A) and Fluorocult LMX Broth
- Colitag

Testing – Enzyme Substrate

Name	Time in hours	Total Coliform Positive	*E. coli* positive
Colilert IDEXX	24 (no more than 28 hrs)	Clear → Yellow	Fluoresces
Colilert-18 IDEXX	18 (up to 22 hrs)	Clear → Yellow	Fluoresces
Colisure IDEXX	24 hours (up to 48 hrs)	Yellow → Magenta	Fluoresces
Colitag™ Colitag	24 ± 2 hrs	Clear → Yellow	Fluoresces
E*Colite™ Charm Sciences	28	Yellow → Blue	Fluoresces
Readycult® EMD Chemicals	24 ± 1 hr	Yellow → Blue	Fluoresces Confirmation by Indole test

Testing

Colilert/Colilert 18 for P/A

- Equipment needed:
  - Incubator
  - UV lamp
  - Comparator
  - pH meter to check tryptic soy broth
- Sample bottle is used in the testing procedure
- Tests for total coliforms and *E. coli* in one step
  - Sample turns yellow if positive for total coliforms
  - Sample turns fluoresces if positive for *E. coli*

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Testing

Colilert/Colilert 18 for P/A cont'd

- Detects a single viable coliform per sample
- For Colilert 18, samples need to be pre-warmed to 35ºC before incubation period starts
- Colilert 18 can lift boil water notices 6 hours earlier than other methods
- Shelf life is 12 months for media packet

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Testing

Colisure

- Step 1
  - Add reagent (shelf life is 12 months) to sample
  - Incubate for 24 hours
    - if samples are not room temperature, they need to be pre-warmed before incubating
- Step 2
  - Read results
    - yellow = negative
    - magenta = total coliform positive
    - magenta/fluorescent = *E. coli* positive

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Testing

Colitag

- Detects 1 CFU of total coliform or *E. coli* bacteria per 100 mL sample
- Acid-resuscitation technology
  - With self adjusting pH level
  - Detects chlorine-injured cells

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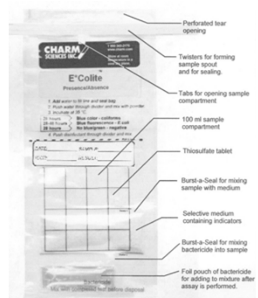
Testing



E*Colite™

- Add water sample to bag
- Push water into the medium compartment
- Incubate at 35ºC for 28 hours
- Info at www.charm.com

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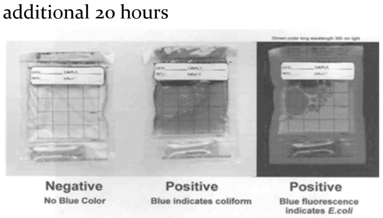
Testing

E*Colite™

- Interpretation
  - If a blue sample does not fluoresce, continue incubating an additional 20 hours



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Testing

Readycult® 100

- Add Readycult® snap packet (3 year shelf life) to 100 mL sample
  - Incubate at 35.5ºC for 24 hours
- Any color change to blue-green (even if only at the upper section of sample) confirms the presence of total coliforms
  - Don't need a color comparator

Negative Positive Coliforms

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Testing

Readycult® 100

- A light blue fluorscence indicates the presence of *E. coli* (94-96% *E. coli* specific)
- If confirmation of *E. coli* is desired, the indole test can be performed directly in the same broth by adding Kovac's reagent (or Bactident® Indole)
  - If a red ring appears immediately, you have positive confirmation

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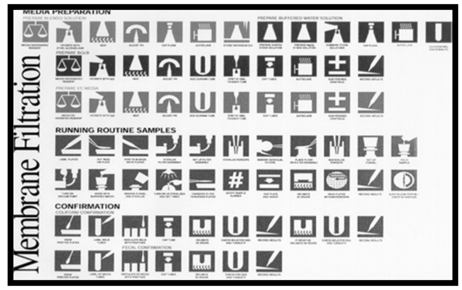
Testing

Membrane Filtration Pictorial



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Testing

Colilert Method Pictorial

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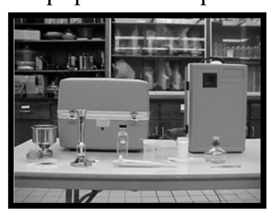
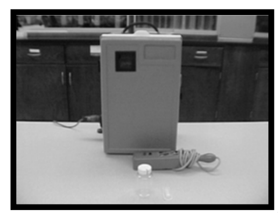
Testing

Equipment Comparison





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Chlorine Residual

- Free chlorine residual must be tested and recorded when bacteriological samples are collected
- Two most common tests:
  - Amperometric titration
    - less interferences as color and/or turbidity
  - DPD (N,N-diethyl-*p*-phenylenediamine)
- Analysis should be performed ASAP
- Exposure to sunlight or agitation of the sample will cause a reduction in the chlorine residual

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Chlorine Residual

- DPD colorimetric method most commonly used
  - Match color sample to a standard
  - ***Swirl sample for 20 seconds*** to mix
  - Within ***one minute*** of adding reagent, place it into colorimeter
- Must maintain a free residual of 0.2 mg/L throughout entire distribution system
  - Chlorine residual must not be less than 0.2 mg/L in more that 5% of samples each month for any two consecutive months

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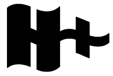
pH



- Power of hydrogen
  - Measurement of the hydrogen concentration
  - Each decrease in pH unit equals 10x increase in acid
- Indicates the intensity of its acidity or basicity
- Scale runs from 0 to 14, with 7 being neutral
- pH probe measures milivolts, then converts into pH units
  - Temperature affects milivolts generated, therefore you need a temperature probe as well for corrections

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pH

- Calibrate daily with fresh buffers
  - Use at least two buffers
- Gel filled probes are not recommended for water industry
  - Water is too clean for probe to make an accurate measurement
- Store probe in slightly acidic solution
- Replace probes yearly

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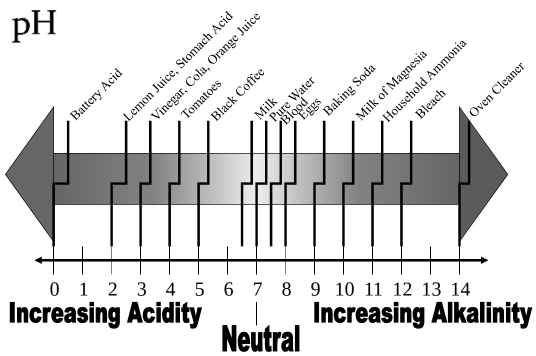
pH



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Fluoride

- Added to drinking water for the reduction of dental caries (cavities)
- Interferences
- Primary MCL = 4.0 mg/L
- Secondary MCL = 2.0 mg/L
- State of Tennessee recommends 0.9 to 1.3 mg/L

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Fluoride

- Methods
  - SPADNS
    - interferences are more common with this test
    - alum or aluminum complexes can interfere
  - Electrode
    - TISAB removes most of the aluminum interferences
    - store probe in a standard, the higher the better
    - probes can last 3-5 years
    - can clean with toothpaste

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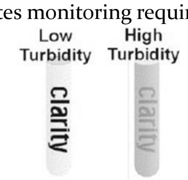
Turbidity

- Physical cloudiness of water
  - Due to suspended silt, finely divided organic and inorganic matter, and algae
- Nephelometric method measures scattered light
  - unit - NTU
- SDWA stipulates monitoring requirements



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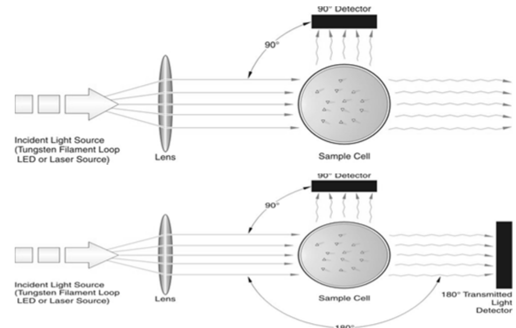
Turbidity

- Measure samples ASAP
- Keep sample tubes clean and scratch free
- Gently mix samples prior to reading
- Calibrate meter at least quarterly
- Records must be kept until next sanitary survey

Turbidimeter



Alkalinity

- Capacity of water to neutralize acids
- Due to presence of hydroxides, carbonates, and bicarbonates
- Many water treatment chemicals (alum, chlorine, lime) alter water quality
- Titration using H_2SO_4 to pH endpoint or color change of indicator

Alkalinity

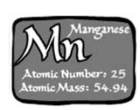
- Expressed as mg/L $CaCO_3$
- Methyl orange or bromcresol green-methyl red measures alkalinity
  - *Standard Methods* makes no mention of methyl orange
  - End point color change may be difficult to see with methyl orange
  - If using bromcresol green-methyl red and water is chlorinated, use sodium thiosulfate to remove chlorine that interferes with the color change

Hardness

- Mainly due to calcium and magnesium ions in solution
- Can cause scale when water evaporates or when heated in water heaters and pipes
- Test involves titration with 0.02 N EDTA standard from a red to a blue endpoint
- Precautions
  - Metal ions may interfere, so an inhibitor may be needed
- Measured as $CaCO_3$, in mg/L

Iron and Manganese

- Can precipitate out in distribution system
- Elevated levels in water can cause staining of plumbing fixtures and laundry
- sMCL for iron is 0.3 mg/L
- sMCL for manganese is 0.05 mg/L



Lead and Copper Rule

- Established by EPA in 1991
- All community and non-community water systems must monitor for lead and copper at customers' taps
- If aggressive water is dissolving these metals, system must take action to reduce corrosivity
- Samples must be take at high risk locations
  - homes with lead service lines
- Water must sit in lines for at least 6 hours
  - first draw
- One liter of sample collected from cold water tap in kitchen or bathroom
- Test results must be maintained for 12 years

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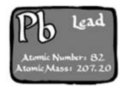
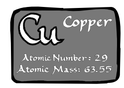
Lead and Copper Rule

- Action levels
  - Lead - 0.015 mg/L
  - Copper - 1.3 mg/L
- If action level is exceeded in more than 10% of samples, steps must be taken to control corrosion
  - Corrosion control program
  - Source water treatment
  - Public Education
  - and/or Lead service line replacement





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Phosphates

- Orthophosphates work well for lead and copper protection
- Polyphosphates work as *sequestering agents* – tie up iron and manganese to prevent color and taste complaints
  - Tie up calcium carbonate as a catalyst
  - Calcium (from alkalinity) is required as a catalyst
  - If low alkalinity, need a blend of polyphosphate and orthophosphate
  - Orthophosphate coats pipe; polyphosphate sequesters

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Phosphates

- Common tests
  - Total phosphates
    - need to be digested before they can be analyzed
  - Ortho-phosphates
    - colorimetric test
    - easily done with Hach test kit
      - reactive phosphates
    - 48 hour hold time

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Total Organic Carbon (TOC)

- High temperature combustion at 950°C
- Sample is injected into a heated reaction chamber packed with oxidative catalyst such as cobalt oxide
- Water is vaporized and the organic carbon is oxidized to CO_2 and H_2O
- CO_2 is transported in the carrier-gas streams and is measured by means of a nondispersive infrared analyzer (NDIR)
- Samples are preserved with sulfuric or phosphoric acid and cooled to 4°C

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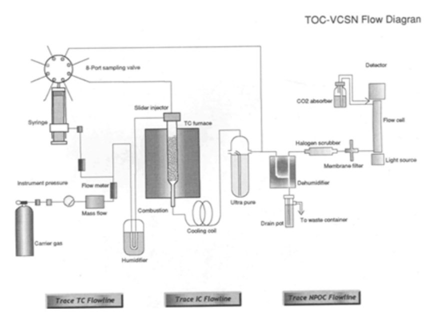
Total Organic Carbon (TOC)



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THM

- Trihalomethane
  - Chloroform
  - Dibromochloromethane
  - Bromodichloromethane
  - Tribromomethane
- MCL = 0.080 mg/L

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HAA5

- Haloacetic acids
  - Monochloracetic acid
  - Dichloroaecitic acid
  - Trichloroacetic acid
  - Monobromoacetic acid
  - Dibromoacetic acid
- MCL = 0.060 mg/L

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LT2ESWTR

- Long Term 2 Enhanced Surface Water
  - Treatment Rule (LT2ESWTR) requires Public Water Systems (PWS) that use surface water or ground water under the direct influence of surface water to monitor their source water for *Cryptosporidium*, *E. coli*, or turbidity for a limited period
  - Based on the results additional treatment techniques may be required for some systems

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LT2

- *Crypto*
  - Methods 1623 or 1622
  - 10L in bulk or filtered
  - Matrix spike samples
- *E. coli*
  - Enumeration, not presence/absence
- Turbidity

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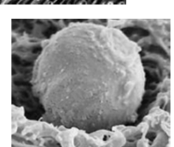
Cryptosporidium (Crypto)

- Protozoan parasite
- Common in surface water
- Resistant to traditional disinfectants
- Can pass through filters
- Causes cryptosporidiosis
- Filtration and alternative disinfectants can remove and/or inactivate



Cryptosporidium Oocyst

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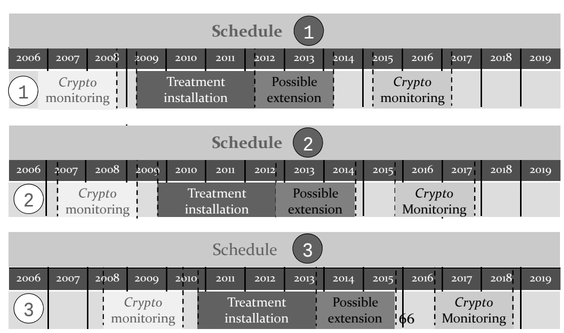
Implementation Time line



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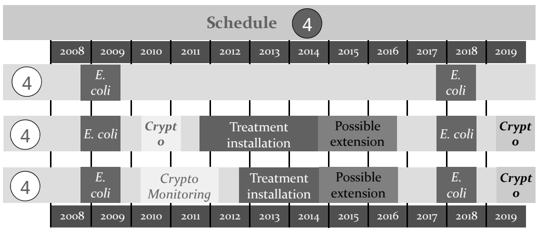
Implementation Time line



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Lab Safety

- Read MSDS for all chemicals used in lab
- Store chemicals properly
- Know where safety equipment is stored
- Never pour water into acid
- CPR and First Aid Training (TOSHA requirement)
- Clean chemical spills immediately
- Follow published lab procedures (*Standard Methods*)
- Read and become familiar with Safety SOP

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Lab Safety

Material Safety Data Sheets (MSDS)

- Keep on file for all chemicals purchased
  - According to the Americans with Disabilities Act of 1990, MSDS's should be kept for a minimum of 30 years
- Includes all information shown on chemical label and more

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Lab Safety

Material Safety Data Sheets (MSDS)

- Must be readily available for employee review at all times you are in the work place
  - The can't be locked in an office or filing cabinet to which you don't have access to
  - If they are on a computer, everyone must know how to access them
- If you request to see a MSDS for a product you use at work and your employer cant show it to you, after one working day you may refuse to work with that product until you are shown the correct MSDS

70

Lab Safety

Material Safety Data Sheets (MSDS)

- Information provided:
  - Common and chemical name
  - Manufacturer info
  - Hazardous ingredients
  - Health hazard data
  - Physical data
  - Fire and explosive data
  - Spill or leak procedures
  - PPE
  - Special Precautions

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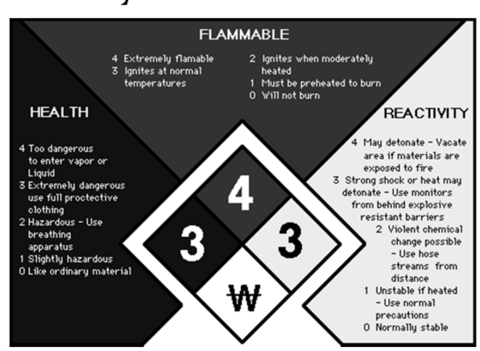
Lab Safety – Chemical Label



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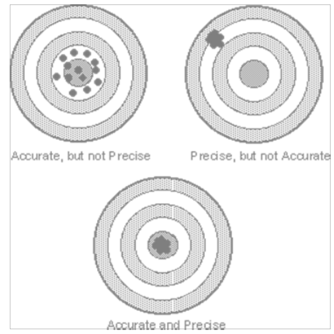
QA/QC Program

- A QA/QC program consists of procedures that ensure the precision and accuracy of tests performed on a daily basis
- Precision - repeatability
  - Shooting at a target and hitting the same spot repeatedly
- Accuracy – closeness of test results to the correct (known) value
  - Shooting at a target and hitting the bull's eye

73

QA/QC Program



74

QA/QC Program

Three Phases

- Keeping records
- Documenting that equipment is regularly calibrated and temperatures are correct
- Perform QC tests to demonstrate precision and accuracy

75

QA/QC Program

Record Keeping

- Maintain a complete and accurate list of exact locations of all sampling sites
- Maintain a complete and accurate list of all test procedures used
  - Record method numbers on bench sheets
- Write in pen
- Initial your entries
- Use a notebook

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QA/QC Program

Quality Control Tests

- Duplicates
- Blanks
- Lab standards
- Unknown lab standards
- Spikes

77

QA/QC Program

Duplicates

- Simplest form of QC test
- Run two tests on one sample
  - This shows how precise the analyst's procedure is
  - Sample results should yield very close results
    - goal is to have no difference
- General recommendation is to run a duplicate every 10 samples

78

QA/QC Program

Common Source of Errors for Duplicates

- Sample size
  - Should be same size
- Insufficient mixing
- Dirty glassware
- Calculation errors
- Reagents
- Titration
  - Misreading burette
- Weighing
- Calibration
- Reagent water

79

QA/QC Program

Blanks

- Can show test interference
- Should be treated as a sample
  - Take through all procedures
  - Add all reagents or incubate along with other samples
- Target value for a blank is zero

80

QA/QC Program

Blanks

- Positive blanks show a problem
  - Bad reagents
  - Bad technique
  - Unclean glassware
  - Bad distilled water

81

QA/QC Program

Blanks

- Coliform tests
  - A blank should never be positive
  - Blanks should be run before you filter samples and when you are done filtering samples
    - if the pre-sample blank has colony growth, the equipment was not properly sterilized
    - if the post-sample blank has colony growth, the equipment was not cleaned well enough between samples

82

QA/QC Program

Laboratory Standards

- Determines accuracy
- If the test value agrees with the true value, the test has been performed accurately
- Mix onsite or purchased from supplier
  - Purchased standards should be the preference because this can reduce the possibility of having mixing errors
  - They also come with a certificate of analysis
- Perform along with duplicates
  - One every 10 samples

83

QA/QC Program

Unknown Laboratory Samples

- EPA quality control unknowns
- Commercially available
- Gives confidence to analyst
- Can show deficiencies in the testing procedure

84

QA/QC Program

Spikes

- Determine accuracy
- A known amount of standard is added to a sample
- The results should equal the sample value plus the added known amount
- Goal is to have 100% recovery of spike and sample
- If you use Hach methods, most have directions on how to spike a sample

85

QA/QC Program

Spikes

- If your sample result was 100 mg/L and you added 50 mg/L into the sample
  - you should yield 150 mg/L

86

QA/QC Program

Other Samples

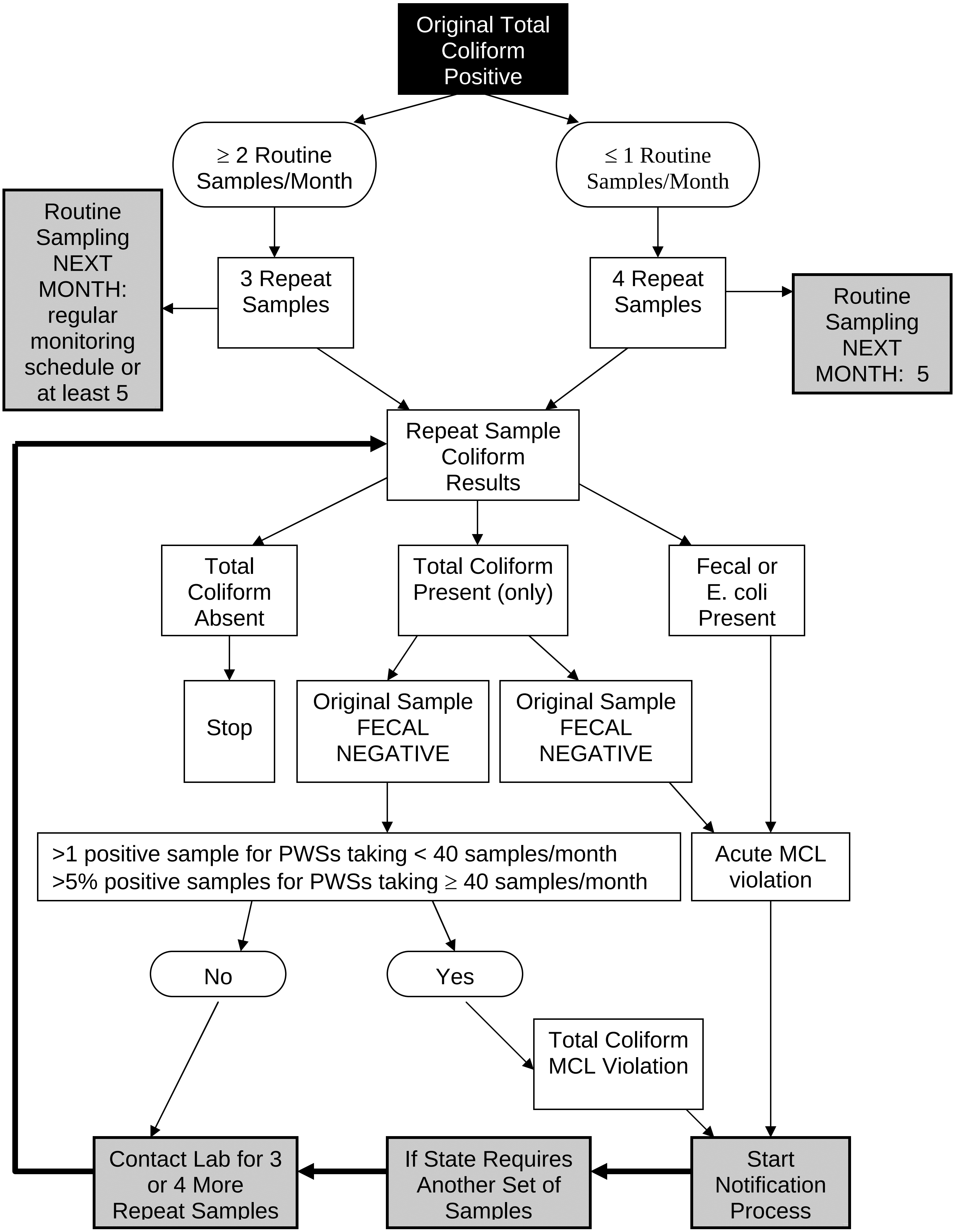
- Some labs split samples with other labs to check the accuracy of the testing procedure
- If you are concerned that your contract lab is getting wrong values, send in a known standard as a sample
  - This does double your cost, but you can see how close they are to the known value
  - Don't tell the contracted lab that the second sample is a known

87

Total Coliform Monitoring Frequency for Community Water Systems

Population Served	Minimum Number of Samples Per Month
25 to 1,000	1
1,001 to 2,500	2
2,501 to 3,300	3
3,301 to 4,100	4
4,101 to 4,900	5
4,901 to 5,800	6
5,801 to 6,700	7
6,701 to 7,600	8
7,601 to 8,500	9
8,501 to 12,900	10
12,901 to 17,200	15
17,201 to 21,500	20
21,501 to 25,000	25
25,001 to 33,000	30
33,001 to 41,000	40
41,001 to 50,000	50
50,001 to 59,000	60
59,001 to 70,000	70
70,001 to 83,000	80
83,001 to 96,000	90
96,001 to 130,000	100
130,001 to 220,000	120
220,001 to 320,000	150
320,001 to 450,000	180
450,001 to 600,000	210
600,001 to 780,000	240
780,001 to 970,000	270
970,001 to 1,230,000	300
1,230,001 to 1,520,000	330
1,520,001 to 1,850,000	360
1,850,001 to 2,270,000	390
2,270,001 to 3,020,000	420
3,020,001 to 3,960,000	450
3,960,001 or more	480

Total Coliform Action Flow Chart



Water Treatment and Distribution
Laboratory Practice Quiz

1. The MCL for total coliform bacteria is based on their ______________ .
   a. Concentration in mg/L
   b. Concentration in colonies per 100 mL
   c. Presence or absence
   d. All of the above
   e. None of the above

2. The sample volume to be used when running a membrane filter test for coliform bacteria is _______________ .
   a. 20 mL
   b. 40 mL
   c. 60 mL
   d. 80 mL
   e. 100 mL

3. Records of bacteriological analyses must be kept at least ________________ .
   a. Until the next sanitary survey
   b. Three years or until the next sanitary survey
   c. Five years
   d. Ten years
   e. Twelve years

4. Analysis of samples for determining bacteriological quality of the water must be started within _____________ hours of collection.
   a. 24
   b. 30
   c. 36
   d. 42
   e. 48

5. A bacteriological bottle contains a white powder which is placed in the bottle in order to _________________ .
   a. Keep the bottle clean
   b. Kill any bacteria present
   c. Remove any chlorine residual
   d. All of the above
   e. None of the above

6. When the membrane filter method for coliform analysis is used, a typical coliform colony will be pink to dark red with a distinctive ___________________ .
   a. Greenish metallic sheen
   b. Dull bluish coating
   c. Shape
   d. All of the above
   e. None of the above

7. Any sample that contains coliform bacteria is a ___________________ sample.
   a. Grab
   b. Negative
   c. Positive
   d. Representative
   e. Routine

8. Any sample that does not contain coliform bacteria is a __________________ sample.
   a. Grab
   b. Negative
   c. Positive
   d. Representative
   e. Routine

9. For bacteriological sample to be useful, it must contain essentially the same constituents as the body of water from which it was taken. This type of sample is called a _________________ sample.
   a. Grab
   b. Flow-proportional time composite
   c. Representative
   d. Time composite

10. To remove any stagnant water from the customer's service line, and to make certain that water from the distribution main is being sampled, flush the faucet for ________ minutes.
    a. 1 – 3
    b. 2 – 5
    c. 5 – 7
    d. 7 – 9
    e. 10 – 15

11. Bottles for collecting samples for bacteriological analyses should ______________ .
    a. Not be rinsed before use
    b. Be rinsed before use
    c. Be completely filled
    d. All of the above
    e. None of the above

12. Bottles for collecting samples for bacteriological analyses contain ______________, which destroys any chorine residual in the sample.
    a. Sodium arsenite
    b. Sodium chloride
    c. Sodium fluoride
    d. Sodium hydroxide
    e. Sodium thiosulfate

13. Samples for bacteriological analysis should not be taken from _________________.
    a. Swivel faucets
    b. Leaking faucets
    c. Faucets with aerators, strainers or hose attachments
    d. All of the above
    e. None of the above

14. A sample which consists of a number of grab samples taken from the same sampling point at different times and mixed together before analysis is called a __________________ sample.
    a. Composite
    b. Grab
    c. Flow-proportional time composite
    d. Representative
    e. Time composite

15. High fluoride readings can result from all of the following causes except _________.
    a. Polyphosphates can interfere with the SPADNS method, resulting in high fluoride readings
    b. Not accounting for natural fluoride in the water
    c. Dilution of water which has been fluoridated with unfluoridated water in storage tanks
    d. All of the above
    e. None of the above

16. What is the secondary maximum contaminant level for fluoride?
    a. 0.2 mg/L
    b. 0.4 mg/L
    c. 2.0 mg/L
    d. 4.0 mg/L

17. The maximum permissible level of a contaminant in water as specified in the regulations of the Safe Drinking Water Act is the __________________________ .
    e. Maximum contaminant level
    f. Saturation point
    g. Zeta potential
    h. All of the above
    i. None of the above

18.___________________ is an indicator used when measuring the total alkalinity concentration on a water sample.
   j. EDTA
   k. Eriochrome black-T
   l. Bromcresol Green Methyl Red
   m. Phenolphthalein
   n. Sodium thiosulfate

19. A(n) ____________________ is a device that sterilizes laboratory equipment by using pressurized steam.
   a. Autoclave
   b. Beaker
   c. Buret
   d. Nepholometer
   e. Pipet

1. C
2. E
3. C
4. B
5. C
6. A
7. C
8. B
9. C
10. B
11. A
12. E
13. D
14. E
15. C
16. C
17. A
18. C
19. A

Section 9

Filtration

FILTRATION

1

OBJECTIVES

- Purpose of filtration
- Types of filters
- Operation and maintenance
- Regulations regarding filters

2

PURPOSE OF FILTRATION

- Removal of particulate impurities and floc
  - Aesthetics – minor reason
  - Main reason – removes microorganisms
- Water passes through material such as bed of sand, anthracite coal, granular activated carbon (GAC), garnet sand or some combination of these materials
- Physical and chemical process
- Groundwater may not require unless iron and manganese removal situations

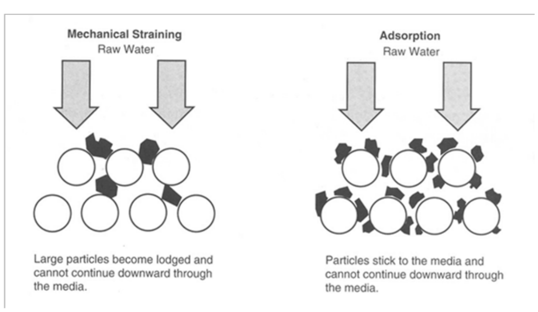
3

PROCESS DESCRIPTION

- Sedimentation on media (very important)
- Adsorption
  - stick to surface, adhere
- Absorption
  - penetration of substance into structure of another substance, like a sponge
- Biological action
- Straining
- All removal mechanisms depend on nature of water being treated and degree of pretreatment as well as filter characteristics

4

PROCESS DESCRIPTION



5

TYPES OF FILTERS

- Conventional
- Direct filtration
- Gravity
  - Slow sand filters
  - Rapid sand filters
  - High-rate filters
- Pressure filtration
  - Sand or mixed-media pressure
  - Diatomaceous earth
- Membrane filters (newer technology)

6

CONVENTIONAL FILTRATION

- Follows complete treatment including coagulation, flocculation, and sedimentation
  - Flocculation - critical step building floc
  - Sedimentation - removes solids to reduce filter loading
- Can be used with high raw turbidity and changing quality surface waters
- Most widely used

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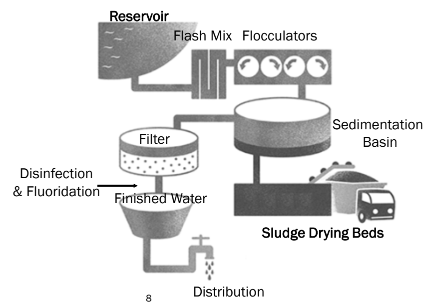
CONVENTIONAL TREATMENT



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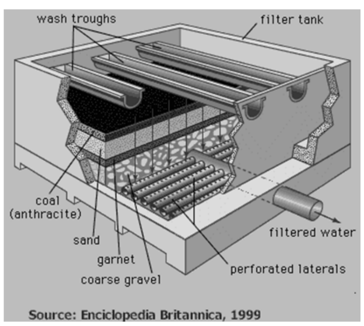
CONVENTIONAL FILTER



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DIRECT FILTRATION

- Sedimentation step is omitted
- Coagulation must occur for solids removal
  - inline flash mixer and flocculation
- Used with consistently low raw water turbidity
  - below 25 NTU
- Must be approved by state (case by case basis)
- Must have dual or mixed media operated at no more that 2 gpm/ft^2
- Many direct filtration plants provide rapid mixing, shorter detention times without agitation (30 to 60 minutes) followed by filtration

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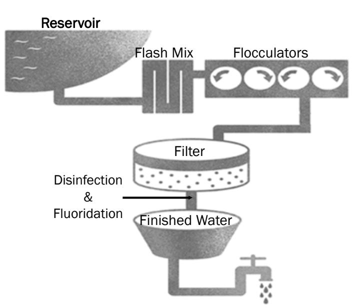
DIRECT FILTRATION



11

GRAVITY FILTERS

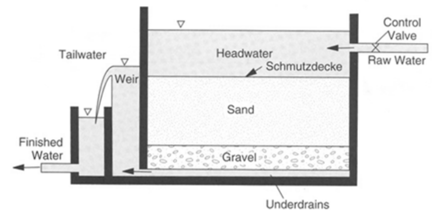
- Open tanks or basins with filter media, gravel and underdrain system
- Water flows through by gravity and is collected in underdrain system

12

GRAVITY FILTERS

- Slow sand filters
  - First type used
  - Have low flow rates
  - Not backwashed
  - Huge land area
  - Not used very often

GRAVITY FILTERS



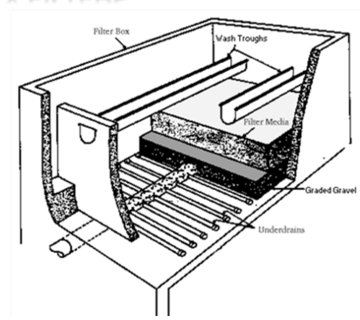
Source: *Barrett et al. (1991).*

FIGURE 6–7 Schematic cross section of a slow sand filter

GRAVITY FILTERS

- Rapid sand filters
  - Backwashed and have higher flow rates with sand media only
- High rate filters
  - Filter at 4 times faster rate than rapid sand filter
  - Filter by combination of straining and adsorption

GRAVITY FILTERS



GRAVITY FILTERS

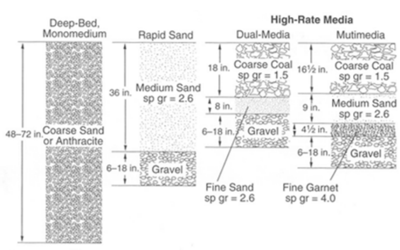
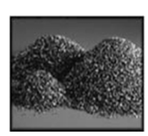


FIGURE 6–8 Comparison of deep-bed, rapid sand, and high-rate filter media

GRAVITY FILTER EQUIPMENT

- Filter tanks
  - Generally rectangular
- Filter media
  - Sand or other media used for filtration

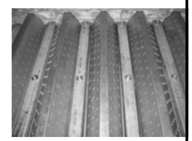


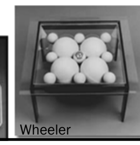

GRAVITY FILTER EQUIPMENT

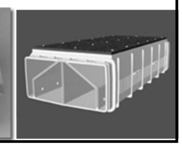
- Underdrain systems
  - Collect the filtered water uniformly across the bottom of the filter so that the filtration rate will be uniform across the filter surface
  - Distribute the backwash water evenly so that the filter bed will expand but not be unduly disturbed

GRAVITY FILTER EQUIPMENT

- Types of Underdrain Systems
  - Pipe lateral collectors
  - Perforated tile bottoms
  - Wheeler filter bottoms
  - Porous plate bottoms
  - False-floor underdrain system

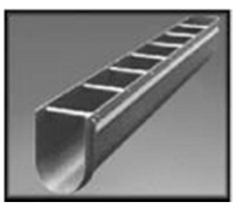






GRAVITY FILTER EQUIPMENT

- Wash-water Troughs
  - Collect the backwash water and also carry it to waste



GRAVITY FILTER EQUIPMENT

- Filter Control Equipment
  - Rapid sand and multimedia filters generally require the following control equipment:
  - Rate of flow controller
    - maintains a fairly constant flow through the filter so that flow surges do not occur
  - Loss of head indicator
    - monitor the status of resistance to flow in the filter as suspended matter builds up in the media
  - Online turbidimeter
    - if the filter effluent is continuously monitored, the filter can be backwashed as soon as the breakthrough starts

TERMS & CONCEPTS

- Head loss
  - the amount of energy used by water in moving from one point to another
- Terminal head loss
  - the head loss in a filter at which water can no longer be filtered at the desired rate because the suspended matter fills the voids in the filter and greatly increases the resistance to flow
    - usually about 8 feet

TERMS & CONCEPTS

- Piezometer
  - instrument that measures pressure head
- Air binding
  - a condition that occurs in filter when air comes out of solution as a result of pressure decreases and temperature increases
    - the air clogs the pores in the filter
    - occurs when water warms as it passes through filter

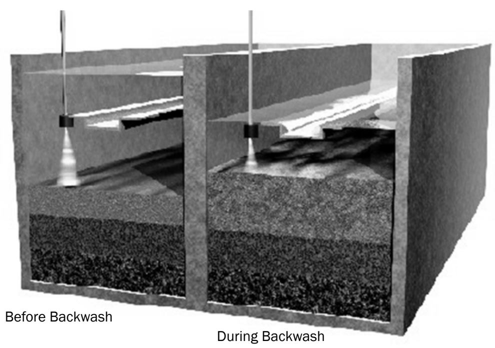
BACKWASHING

- Solids trapped by adsorption and straining
- Solids clog openings through the filter and head loss increases
- Breakthrough of turbidity can occur
- Terminal head loss occurs at 8 feet
- Backwash rate of 15-20 gpm/ft^2 maximum
- If rate too high - may lose expensive media

BACKWASHING

- If rate too low - filter will not be effectively cleaned
- Media grains separate and expand 50% as solids are flushed out
- Air scour in lieu of surface wash becoming popular
- Backwash water must be piped to waste
- Only finished water to be used for backwashing
- Water supply required for at least 15 minutes
- Rewash cycle for at least 5 minutes

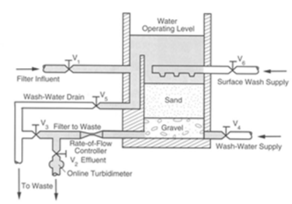
BACKWASHING



Before Backwash

During Backwash

BACKWASHING



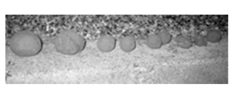
Valve Position During Filtration

Valve	*Filtering*	*Backwashing*	*Filtering to Waste*
V_1 — Influent	Open	Closed	Open
V_2 — Effluent	Open	Closed	Closed
V_3 — Filter to Waste	Closed	Closed	Open
V_4 — Wash-Water Supply	Closed	Open	Closed
V_5 — Wash-Water Drain	Closed	Open	Closed
V_6 — Surface Wash Supply	Closed	Open	Closed

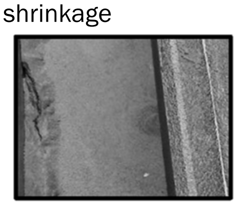
BACKWASHING

Abnormal Conditions

- Mudball in media



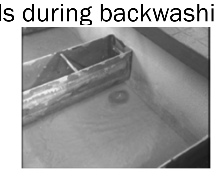
- Media cracked or shrinkage



BACKWASHING

Abnormal Conditions

- Media boils during backwashing



- Excessive media loss or visible disturbance
- Short filter runs

BACKWASHING

Abnormal Conditions

- Filters that will not come clean during backwashing
- Algae on walls and media
- Rapid heat loss
- Air binding
- Turbidity breakthrough
- Turbidity remains high after rewash

BACKWASHING

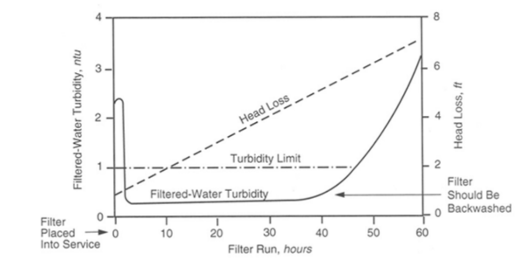


FIGURE 6–27 Typical filter run

BACKWASHING

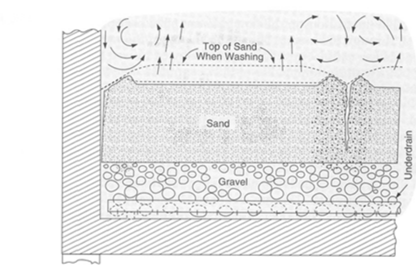


FIGURE 6–32 Clogged filter bed

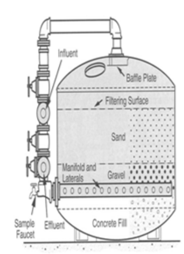
PRESSURE FILTERS

- Similar to gravity sand filter
- Filter is completely enclosed in a cylindrical steel tank
  - + horizontal or vertical
- Operated under pressure
- Same media as gravity filters
  - + anthracite and sand
- Underdrain similar to gravity filters
  - + gravel and conduits collect effluent and distribute wash water
- Air binding in filter does not occur because minimum pressure of 20-25 psi

PRESSURE FILTERS

- Can be used to remove oxidized iron and manganese
- May be installed with an auto backwash
- Principle disadvantage
  - + filter bed cannot be observed during operation
- Max rates of filtration are in the 2-3 gpm/ft^2 range
- Lower installation and operation costs in small plants
- Schmutzdecke characteristic of sand filters

PRESSURE FILTERS



Courtesy of Celite Corporation

FIGURE 6-37 Vertical sand pressure filter tank

DIATOMACEOUS EARTH FILTERS

- Also called *pre-coat filters*
- Used by some small systems
  - extensively used to filter swimming pool water
- Can be operated under pressure or vacuum
- May be installed vertically or horizontally
- Media is skeletal remains of *diatoms*
  - microscopic aquatic plants
  - almost pure silica
- Primarily a straining process

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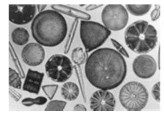
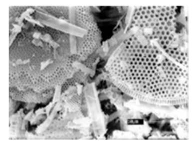
DIATOMACEOUS EARTH FILTERS





Diatoms

- Marine organism with silicate "glass-like shells"
- Deposits on ancient ocean floors are now mined diatomaceous earth
- Used as filter media because of its high porosity
- Also used as and abrasive for cleaning, metal polishes, and some toothpastes

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DIATOMACEOUS EARTH FILTERS

- Wide application where very high particulate removal is required
- Thickness of initial layer of pre-coat media is 1/8 to 1/4 inch
- Use is limited because of difficulty of maintaining effective filter cake at all times
- Microorganisms can pass through defective filter cake
- Filtered water needs to be monitored
- Low initial costs but higher operating costs

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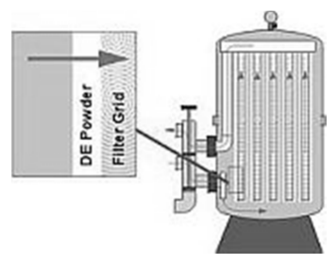
DIATOMACEOUS EARTH FILTERS



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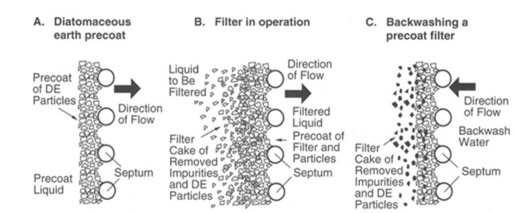
DIATOMACEOUS EARTH FILTERS



Courtesy of Celite Corporation

FIGURE 6–39 Operation of a diatomaceous earth filter

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REGULATORY RATES OF FILTRATION

Design Criteria

- Standard rate of filtration
  - 2 gpm/ft^2 for turbidity
  - 3 gpm/ft^2 for iron removal
- High rate of filtration
  - 4 gpm/ft^2 or turbidity or iron removal under certain conditions
  - Higher than 4 gpm/ft^2 may be approved by state on a case by case basis
- New regulatory requirements for max turbidity on filters in effect – report when exceed

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FILTRATION PROCESS CHANGES

- Coagulant type change
  - cold vs. warm weather
- Adjust coagulant dosage
- Adjust flash mixer/flocculator mixing intensity
- Change frequency of sludge removal
- Decrease or terminate filter aid feed
- Adjust backwash cycle
  - rate, duration

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FILTRATION PROCESS CHANGES

- Remove mudballs
- Replenish lost media
- Clear underdrains
- Check head loss indicators or calibrate
- Pre-chlorinate
- Adjust rate of flow

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MAINTENANCE OF FILTERS

- Pressure filters should be taken apart and inspected annually
- Core samples taken to check for proper stratification of layers
- Underdrain systems may need repairs
- Visually and regularly monitor media depth and replenish as necessary
  - keep stock of media

45

MAINTENANCE OF FILTERS

- Keep records of backwashing
- Install backwash turbidimeters
- Perform scheduled maintenance on valves, pumps and other equipment
- Particle counters
- Install sample lines for each filter and monitor with grab samples

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DESIGN CRITERIA FOR FILTERS (4.2)

- 4.2.1 Gravity Filters
  - (a) Must have at least 2 units
  - (e)(3) Must be enclosed in a building
  - (e)(6) Minimum water depth over surface of sand of 3 feet
  - (e)(8) Prevention of floor drainage to the filter with a minimum 4 inch curb around the filters
  - (g)(1)(i) Sand depth of at least 30 inches

47

DESIGN CRITERIA FOR FILTERS (4.2)

- 4.2.1 Gravity Filters cont'd
  - (g)(2) Dual Media:
    - (g)(2)(iii) Anthracite layer shall not exceed 20 inches in a 30 inch bed
  - (i)(1)(i) Surface or subsurface wash shall provide water pressures of 45-75 psi, except for iron removal only

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DESIGN CRITERIA FOR FILTERS (4.2)

- 4.2.1 Gravity Filters cont'd
  - (j) The following shall be provided for every filter:
    - (j)(1) Sampling tap on the effluent line
    - (j)(2) Indicating loss-of-head
    - (j)(5) Turbidimeter with recorder reading in NTU's on effluent line of each filter

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DESIGN CRITERIA FOR FILTERS (4.2)

- 4.2.1 Gravity Filters cont'd
  - (l) roof drains shall not discharge into the filters or basins and conduits preceding the filters. All filters must be enclosed.

50

DESIGN CRITERIA FOR FILTERS (4.2)

- 4.2.2 Pressure Filters
  - (b) The filters shall be designed to provide for:
    - (b)(3) Filtration and backwashing of each filter individually
    - (b)(5) Top of wash water trough at least 18 inches above surface of media
    - (b)(6) Underdrain system to collect filtered water to distribute backwash water at a rate not less than 15 gpm/ft^2

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DESIGN CRITERIA FOR FILTERS (4.2)

- 4.2.2 Pressure Filters cont'd
    - (b)(7) Backwash flow indicators and a means to observe the wastewater during backwashing
    - (b)(9) Manhole for entry during repairs and inspections
    - (b)(12) Depth of media same as gravity filters (30 inches)

52

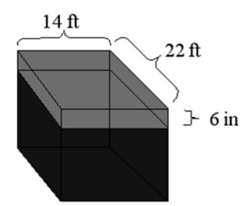
Filter Math

1

Filter Rate (Hook Gauge)

2

- A filter measures 22 ft by 14 ft. The influent is closed and the effluent is opened. The water level drops 6 inches in 120 sec, 124 sec and 128 sec during three tests. What is the filter rate in gpm? and gpm/ft^2?



Filter Rate Steps (Hook Gauge)

3

- Find volume in gallons
- Find average time in minutes
- Find sand bed area in ft^2

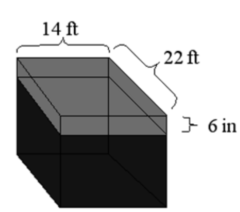
Volume, gal

4

$$V=(L, ft)(W, ft)(d, ft)(7.48\ gal/ft^3)$$

$$V=(22\ ft)(14\ ft)(0.5\ ft)(7.48\ gal/ft^3)$$

$$V= 1151.9\ gal$$



Average Time, min

5

120 sec, 124 sec and 128 sec

$$\text{Avg time, min} = \frac{sec_1 + sec_2 + sec_3}{(3)(60\ sec/min)}$$

$$\text{Avg Time, min} = \frac{120+124+128}{(3)(60\ sec/min)}$$

Avg Time, min = 2.0667 min

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Sand Bed Area

6

A filter measures 22 ft by 14 ft.

Sand Area, ft^2 =(length, ft)(width, ft)

Sand Area, ft^2 = (22 ft)(14 ft)

Sand Area, ft^2 = 308 ft^2

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Filter Rate, gpm (Hook Gauge)

7

$$\text{Filter rate, gpm (Hook Gauge)} = \frac{\text{volume, gal}}{\text{average time, min}}$$

$$\text{Filter rate, gpm} = \frac{1151.9\ gal}{2.0667\ min}$$

Filter rate, gpm = 557.4 gpm

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Filter Rate, gpm/ft^2

8

$$\text{Filter rate, gpm/ft}^2 = \frac{\text{filter rate, gpm}}{\text{sand area, ft}^2}$$

$$\text{Filter rate, gpm/ft}^2 = \frac{557.4\ gpm}{308\ ft}$$

Filter rate, gpm/ft^2 = 1.8 gpm/ft^2

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Backwash Volume

9

- A filter sand area measures 32 ft by 20 ft. Assuming a backwash rate of 20 gpm/ft^2 and a backwash time of 10 minutes, how many gallons of backwash water are required?

Backwash, gal = (rate, gpm/ft^2)(time, min)(area, ft^2)

= (20 gpm/ft^2)(10 min)(32 ft)(20 ft)

= 128,000 gal

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Filter Efficiency

10

- During a filter run of 95 hours, a total of 3.78 MG was filtered. If 35,000 gallons were used to backwash, calculate the % of the filtered water used for backwashing.

$$\% \text{ water used} = \frac{(\text{water used, gal})(100)}{\text{water produced, gal}}$$

$$= \frac{(35{,}000 \text{ gal})(100)}{3{,}780{,}000 \text{ gal}}$$

$$= 0.9\ \%$$

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	Slow Sand Filter	**Rapid Sand Filter**	**Pressure Filter**	**Diatomaceous earth filter (Diatomite filter)**
Filtration rate (GPM/ft^2)	0.015-0.15	2-3	2-3	1-2
Pros	Reliable. Minimum operation and maintenance requirements. Usually does not require chemical pretreatment.	Relatively small and compact.	Lower installation and operation costs in small filtration plants.	Small size. Efficiency. Ease of operation. Relatively low cost. Produces high clarity water. Usually does not require chemical pretreatment.
Cons	Large land area required. Need to manually clean filters.	Requires chemical pretreatment. Doesn't remove pathogens as well as slow sand filters.	Less reliable than gravity filters. Filter bed cannot be observed during operation.	Sludge disposal problems. High head loss. Potential decreased reliability. High maintenance and repair costs.
Filter Media	Sand.	Sand. Or sand and anthracite coal. Or sand and anthracite coal and garnet.	Sand. Or sand and anthracite coal. Or sand and anthracite coal and garnet.	Diatomaceous earth.
Gravity or Pressure?	Gravity.	Gravity.	Pressure.	Pressure, gravity, or vacuum.
Filtration Mechanism	Biological action, straining, and adsorption.	Primarily adsorption. Also some straining.	Primarily adsorption. Also some straining.	Primarily straining.
Cleaning Method	Manually removing the top 2 inches of sand.	Backwashing.	Backwashing.	Backwashing.
Common Applications	Small groundwater systems.	Most commonly used type of filter for surface water treatment.	Iron and manganese removal in small groundwater systems.	Beverage and food industries and swimming pools. Smaller systems.

Filter Vocabulary

______1. Adsorption
______2. Head Loss
______3. NTU
______4. Polymer
______5. Schmutdecke
______6. Underdrain
______7. Breakthrough
______8. Pressure-sand
______9. Piezometer
______10. Cationic
______11. Backwash
______12. Nematodes
______13. Conventional Filtration
______14. Precipitate
______15. Anionic
______16. Diatom
______17. Percolation
______18. Nonionic
______19. Surface Wash
______20. Filter Sand
______21. Anthracite
______22. Mudball
______23. Gravel Bed
______24. Sand Boil
______25. Gravity Filter
______26. Terminal Head Loss
______27. Turbidity

A. A type of coal used as a filter media.
B. Type of algae containing silica in its cell walls.
C. Instrument used to measure pressure by locating the free water surface.
D. Part of the filter that collects filtered water.
E. Sticking to the surface of another material
F. Amount of dirt in the water.
G. When turbidity causing materials begin to pass through the filter.
H. Deep vertical movement of water through a filtering material.
I. Substance that settles out of a solution due to chemical reaction.
J. Filter media support.
K. Reversal of flow through the media to clean out trapped particles.
L. Synthetic compound that consists of long chains of repeating segments.
M. Negative charge.
N. Resistance, due to suspended particles, at which water can no longer be filtered at the desired rate.
O. Sand designed specifically to be used as filter media.
P. Filtration following coagulation / flocculation / sedimentation.
Q. Cylindrical, parasitic worms.
R. Filter under pressure where the water is forced through media by pumping.
S. No charge.
T. Sticky mat formed on top of slow-sand filter.
U. Filter agitation.
V. Resistance to filtration due to buildup on the filter.
W. Violent washing action due to uneven distribution of backwash water.
X. Nephelometric Turbidity Unit
Y. Accumulation of media grains and suspended matter.
Z. Filter in which gravity is the driving force.
AA. Positive Charge

Filter Questions

1. What is the major purpose of filtration?

2. What is turbidity?

3. What are three important reasons for removing turbidity?

4. What is the most important mechanism for removing suspended material from water and how does it work?

5. What are three major disadvantages of a slow-sand filter?

6. What functions do the filter underdrain perform?

7. Why are filter surface washers used?

8. What are high-rate filters?

9. What is the major disadvantage of pressure-sand filters?

10. What is diatomaceous earth?

11. Compare the two basic types of filtration processes used in the United States.

12. What are the three basic filtration steps?

13. What is the major disadvantage of a rate-of-flow controller?

14. Generally, when should a filter be backwashed?

15. Why should filtering to waste be practiced?

16. Why are filter aids used?

17. What three major areas result in most of the operating problems with the filtration process?

18. What problems does poor backwashing cause?

19. What are mudballs and how can they be prevented?

20. What parameters should be monitored continuously for good control of filter operation?

Answers to Vocabulary and Questions

Vocabulary:

1.	E	10.	AA	19.	U
2.	V	11.	K	20.	O
3.	X	12.	Q	21.	A
4.	L	13.	P	22.	Y
5.	T	14.	I	23.	J
6.	D	15.	M	24.	W
7.	G	16.	B	25.	Z
8.	R	17.	H	26.	N
9.	C	18.	S	27.	F

Questions:

1. To remove suspended solids.
2. A measurement of suspended material in water, which can include floc, microorganisms, silt and chemical precipitates.
3. Turbidity (1) interferes with the disinfection process by shielding the microorganisms from the disinfectant; (2) combines chemically with the disinfectant leaving less disinfectant to kill the microorganisms; (3) causes deposits in the distribution system that create tastes, odors and bacterial growths.
4. Adsorption. As the water passes through the filter bed, the suspended materials contact and adsorb onto the surface of the grains of filter media or onto previously deposited materials.
5. (1) Water must be wasted until the schmutzdecke forms; (2) chemical coagulation can't be used because the floc would quickly clog the filter; (3) flow rates are very low; therefore, large areas of land are required for these filters
6. (1) evenly distribute the backwash water; (2) uniformly collect the finished water
7. They assist in breaking up and washing away the accumulated material in the upper part of the filter bed.
8. Filters that use a combination of filter media (graded coarse-to-fine) in the filter bed. High-rate filters operate at rates three to four times those of rapid-sand filters.
9. The filter bed can't be observed during operation.
10. The skeletal remains of microscopic aquatic plants called diatoms.
11. Conventional filtration is effective for practically any level of turbidity in raw water. Flocculation, coagulation and sedimentation occur ahead of the filtration process. Direct filtration does not involve the use of a sedimentation process. Consequently, it should only be used when raw-water turbidity is below 25 NTU and color is below 25 color units (CU's). Dual- or multi-media filters should always be used and should be monitored closely to prevent turbidity breakthrough since filter rates are higher.
12. (1) filtering, (2) backwashing, (3) filtering to waste
13. The need for frequent maintenance. A malfunctioning controller can damage the filter bed and cause poor treated-water quality.
14. When any one of the following occurs: (1) terminal head loss is reached, (2) breakthrough starts to occur, (3) a filter run reaches 36 hours.
15. To prevent any filtered material that remains in the filter bed after backwashing from entering the treated water.

16. To strengthen the bonds between floc particles and coat the media grains to improve adsorption. This allows the floc to resist the shearing forces of water as it flows through the media.
17. (1) Chemical treatment before filtration, (2) control of filter flow rate, (3) backwashing
18. (1) Mudball formation, (2) filter bed shrinkage and cracking, (3) gravel displacement
19. Mudballs are clumps of filter media grains stuck together with floc material. They can be prevented by using adequate backwash flow rates and filter agitation.
20. Head loss and filtered water turbidity.

Section 10

Pumps

Pumps

Water Treatment

Objectives

- To learn the different kinds of pumps used in water and wastewater systems
- To learn proper operating procedures
- To learn the mechanical parts of pumps
- To learn the preventive maintenance and safety concerning pumps

Necessity of Pumps

- Pumps are required when gravity cannot supply water with sufficient pressure to all parts of the distribution system
- Pumps account for the largest energy cost for a water supply operation

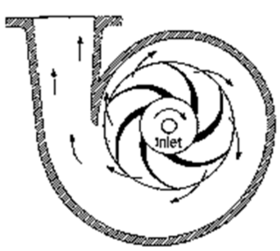
Types of Pumps

- Velocity Pumps

- Positive Displacement Pumps

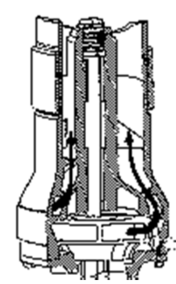
Velocity Pumps

- Spinning impeller or propeller accelerates water to high velocity in pump casing



Velocity Pumps

- High velocity, low pressure water is converted to low velocity, high pressure water



Velocity Pumps

Design Characteristics

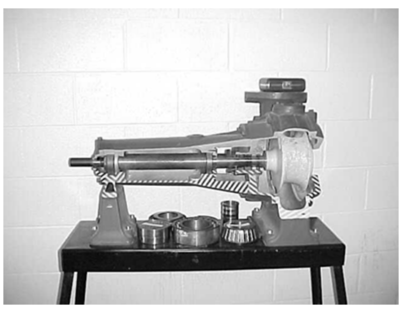
- Axial flow designs
  - Propeller shaped impeller adds head by lifting action on vanes
  - Water moves parallel to pump
  - High volume, but limited head
  - Not self-priming

Velocity Pumps

Design Characteristics

- Radial flow designs
  - Water comes in through the center (eye) of impeller
  - Water thrown outward from impeller to diffusers that convert velocity to pressure
- Mixed flow designs
  - Has features of axial and radial flow
  - Works well for water with solids

Velocity Pumps



Velocity Pumps

Types

- Centrifugal (volute) pumps
- Turbine pumps
- Jet Pumps

Velocity Pumps

Centrifugal Pumps

- Volute-casing type most commonly used in water utilities
- Radial flow - impeller rotates in casing
- Single or multi-stage
- By varying size, shape, and width of impeller, a wide range of flows and pressures can be achieved

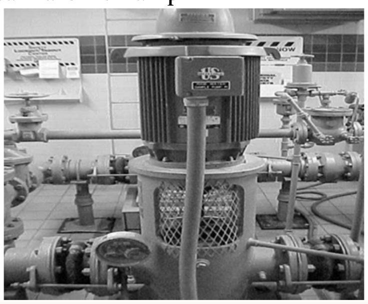
Velocity Pumps

- Open Impeller

- Double Suction Closed Impeller

Velocity Pumps

- Vertical Turbine Pump



Velocity Pumps

Vertical Turbine Pumps

- Deep-well pump – drive unit at surface; lower shaft and impeller are submerged
  - Requires careful alignment at installation
- Submersible pump – can operate while submerged; entire unit below water (in a well)
- Booster pump – increases pressure in distribution system, supply water to storage tank

Velocity Pumps

Vertical Turbine Pumps

- Impeller rotates in a channel of constant cross-sectional area
- Mixed or radial flow
- Create highest head available from velocity pumps
- Backflow limited
- Efficiencies up to 95% possible
- Water must be very clean

Velocity Pumps

Jet Pumps

- Part of discharge is used to help run ejector
- Lower efficiency
- Used for small wells

Velocity Pumps

Positive-Displacement Pumps

- Less efficient than centrifugal pumps
- Used for smaller volume of liquid
- More precise
- Mostly used for chemical feed

Velocity Pumps

Peristaltic Chemical Pump

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Velocity Pumps

Positive-Displacement Diaphragm Pump

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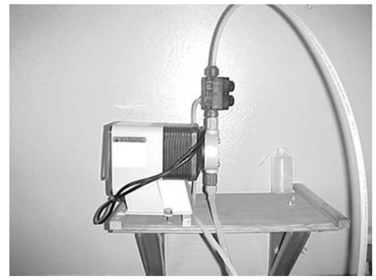
Velocity Pumps

Diaphragm Pump for Polymers



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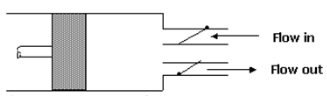
Velocity Pumps

Positive-Displacement Pumps

- Reciprocating (piston) pump
  - Piston moves back and forth in cylinder
  - Liquid enters and leaves through check valves



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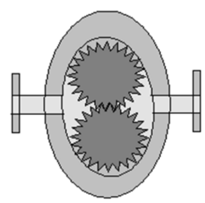
Velocity Pumps

Positive-Displacement Pumps

- Rotary pump
  - Use lobes or gears to move liquid through pump



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Centrifugal Pump Operation

- Pump starting and stopping
  - Impeller must be submerged for a pump to start
  - Foot valve helps hold prime
  - Discharge valve should open slowly to control water hammer
  - In small pumps, a check valve closes immediately when pump stops to prevent flow reversal
  - In large pumps, discharge valve my close before pump stops

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Centrifugal Pump Operation

Flow Control

- Flow usually controlled by starting and stopping pumps
- Throttling flow should be avoided
  - wastes energy
- Variable speed drives or motor are best way to vary flow

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Centrifugal Pump Operation

Monitoring Operational Variables

- Suction and discharge heads
  - pressure gauges
- Bearing and motor temperature
  - Temperature indicators can shut down pump is temp gets too high
  - Check temperature of motor by feel

Centrifugal Pump Operation

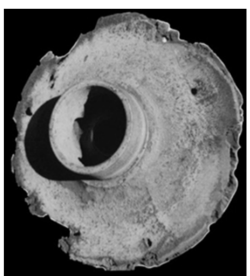
Monitoring Operational Variables

- Vibration
  - Detectors can sense malfunctions causing excess vibration
  - Operators can learn to distinguish between normal and abnormal sounds

Centrifugal Pump Operation

Monitoring Operational Variables

- Speed
  - *Cavitation* can occur at low and high speeds
    - cavitation – the creation of vapor bubbles due to partial vacuum created by incomplete filling of the pump



Mechanical Details of Centrifugal Pumps

- Casing
  - Housing surrounding the impeller
    - also called the *volute*
  - Designed to minimize friction loss as water is thrown outward from impeller
  - Usually made of cast iron, spiral shape

Mechanical Details of Centrifugal Pumps

- Single-suction pumps
  - Also called *end-suction pumps* used for small water systems
  - Water inlet at one end, discharge at right angle
  - Water enters parallel to shaft, exits perpendicular to shaft
  - Two types, based on how impeller shaft is connected to motor

Mechanical Details of Centrifugal Pumps

- Double-suction pumps
  - Water enters from both sides
  - Commonly called *horizontal split-case*
  - Can pump over 10,000 gpm

Mechanical Details of Centrifugal Pumps

- Impeller
  - Rotating element in pump
  - Made of bronze or stainless steel
  - Usually closed design
    - some single-suction have semi open
- Wear rings
  - Restrict flow between impeller discharge and suction
  - Leakage reduces pump efficiency

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Mechanical Details of Centrifugal Pumps

- Shaft
  - Connects impeller to pump
  - Steel or stainless steel
- Shaft sleeves
  - Protect shaft from wear from packing rings
- Packing rings
  - Seal the space between shaft and casing
  - Has graphite or other lubricating substance

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Mechanical Details of Centrifugal Pumps

- Lantern rings
  - Perforated ring placed in stuffing box
  - Forms seal around shaft
  - Lubricates packing
- Mechanical seals
  - Required instead of packing rings for suction head greater than 60 psi
  - Prevents water from leaking along shaft
  - Keeps air out of pump

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Mechanical Details of Centrifugal Pumps

- Bearings
  - Antifriction devices for supporting and guiding pump and motor shafts
  - Usually get noisy as they wear out
- Couplings
  - Connect pump and motor shafts
  - Available in dry or lubricated
    - Lubricated requires grease at 6 month intervals
    - Dry has a rubber or elastomer membrane that requires no lubrication

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Mechanical Details of Centrifugal Pumps

Advantages of Mechanical Seals

- Last longer - from 3 to 5 years
- More protection for shaft sleeve when they fail
- Continual adjusting, cleaning or repacking is not required
- Less chance of flooding a lift station from failure

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Mechanical Details of Centrifugal Pumps

Limitations of Mechanical Seals

- High initial cost
- More competence and special tools to replace
- Pump must be shut down upon failure
- Pump dismantled to replace seal
- Seals often require special handling when installed

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Pump Bearings

- Usually last for years, if serviced properly
- Causes of failure
  - contamination
  - fatigue failure
  - thrust failure
  - misalignment
  - electric arching
  - lubrication failure
    - too much, too little, contaminated with grease/oil, wrong type

Starting a New Pump

- Lubricate properly
- Turn shaft by hand to ensure rotation is free
- Check to see if the shafts of pump and motor are aligned and flexible coupling is aligned
- Check electric current characteristics of motor and inspect wiring
- Ensure pump is primed
- Never operate a positive-displacement pump or progressive cavity type with the discharge line closed

Pump Shutdown

- For long periods, ensure the motor disconnect switch is open, locked out and tagged
- Close all valves on the suction and discharge side
- Completely drain the pump and remove the vent and drain plugs
- Do not permit sludge to remain in pumps or piping
- Inspect all bearings
- Drain the bearing housing and add fresh lubricant

Inspection and Maintenance

- Inspection and maintenance schedule prolongs life of pumps
  - necessary for warranty
- Keep records of all maintenance on each pump
- Keep log of operating hours

Pump Safety

- Machinery should always be turned off and locked out/tagged out before any work is performed on it
- Make sure all moving parts are free to move and all guards are in place before restarting

Pump Vocabulary

1. Axial-Flow Pump – a pump in which a propeller-like impeller forces water out in the direction parallel to the shaft. Also called a propeller pump.
2. Bearing – anti-friction device used to support and guide a pump and motor shafts.
3. Casing – the enclosure surrounding a pump impeller, into which the suction and discharge ports are machined.
4. Cavitation – a condition that can occur when pumps are run too fast or water is forced to change direction quickly. A partial vacuum forms near the pipe wall or impeller blade causing potentially rapid pitting of the metal.
5. Centrifugal Pumps – a pump consisting of an impeller on a rotating shaft enclosed by a casing having suction and discharge connections. The spinning impeller throws water outward at high velocity, and the casing shape converts this velocity to pressure.
6. Closed-Coupled Pump – a pump assembly where the impeller is mounted on the shaft of the motor that drives the pump.
7. Diffuser Vanes – vanes installed within a pump casing on diffuser centrifugal pumps to change velocity head to pressure head.
8. Double-Suction Pump – a centrifugal pump in which the water enters from both sides of the impeller. Also called a split-case pump.
9. Foot Valve – a check valve placed in the bottom of the suction pipe of a pump, which opens to allow water to enter the suction pipe but closes to prevent water from passing out of it at the bottom end. Keeps prime.
10. Frame-Mounted Pump – a centrifugal pump in which the pump shaft is connected to the motor shaft with a coupling.
11. Impeller – the rotating set of vanes that forces water through the pump.
12. Jet Pump – a device that pumps fluid by converting the energy of a high-pressure fluid into that of a high-velocity fluid.
13. Lantern Ring – a perforated ring placed around the pump shaft in the stuffing box. Water from the pump discharge is piped to this ring. The water forms a liquid seal around the shaft and lubricates the packing.
14. Mechanical Seal – a seal placed on the pump shaft to prevent water from leaking from the pump along the shaft; the seal also prevents air from entering the pump.
15. Mixed-Flow Pump – a pump that imparts both radial and axial flow to the water.
16. Packing – rings of graphite-impregnated cotton, flax, or synthetic materials, used to control leakage along a valve stem or a pump shaft.
17. Packing Gland – a follower ring that compressed the packing in the stuffing box.
18. Positive Displacement Pump – a pump that delivers a precise volume of liquid for each stroke of the piston or rotation of the shaft.
19. Prime Mover – a source of power, such as an internal combustion engine or an electric motor, designed to supply force and motion to drive machinery, such as a pump.

20. Radial-Flow Pump – a pump that moves water by centrifugal force, spinning the water radially outward from the center of the impeller.
21. Reciprocating Pump – a type of positive-displacement pump consisting of a closed cylinder containing a piston or plunger to draw liquid into the cylinder through an inlet valve and forces it out through an outlet valve.
22. Rotary Pump – a type of positive-displacement pump consisting of elements resembling gears that rotate in a close-fitting pump case. The rotation of these elements alternately draws in and discharges the water being pumped.
23. Single-Suction Pump – a centrifugal pump in which the water enters from only one side of the impeller. Also called an end-suction pump.
24. Stuffing Box – a portion of the pump casing through which the shaft extends and in which packing or a mechanical seal is placed to prevent leakage.
25. Submersible Pump – a vertical-turbine pump with the motor placed below the impellers. The motor is designed to be submersed in water.
26. Suction Lift – the condition existing when the source of water supply is below the centerline of the pump.
27. Velocity Pump – the general class of pumps that use a rapidly turning impeller to impart kinetic energy or velocity to fluids. The pump casing then converts this velocity head, in part, to pressure head. Also known as kinetic pumps.
28. Vertical Turbine Pump – a centrifugal pump, commonly of the multistage, diffuser type, in which the pump shaft is mounted vertically.
29. Volute – the expanding section of pump casing (in a volute centrifugal pump), which converts velocity head to pressure head..
30. Water Hammer – the potentially damaging slam that occurs in a pipe when a sudden change in water velocity (usually as a result of too-rapidly starting a pump or operating a valve) creates a great increase in water pressure.
31. Wear Rings – rings made of brass or bronze placed on the impeller and/or casing of a centrifugal pump to control the amount of water that is allowed to leak from the discharge to the suction side of the pump.

Pump and Motor Facts

Pump Facts

High-service pump – discharges water under pressure to the distribution system.

Booster pump – used to increase pressure in the distribution system and to fill elevated storage tanks.

Impeller or centrifugal pump used to move water.

Likely causes of vibration in an existing pump/motor installation:

1. bad bearings
2. imbalance of rotating elements
3. misalignment from shifts in underlying foundation

Pump and motor should be tested and complete test results recorded as a baseline for the measurement of performance within the first 30 days of operations.

Calipers and thickness gauges can be used to check alignment on flexible couplings.

Packing/Seals Facts

If new packing leaks, stop the motor and repack the pump.

Pumps need new packing when the gland or follower is pulled all the way down.

The packing around the shaft should be tightened just enough to allow an occasional drop of liquid.

Joints of packing should be staggered at least 90°.

Mechanical seals consist of a rotating ring and stationary element.

The operating temperature on a mechanical seal should never exceed 160°F.

Motor Facts

Motors pull the most current on start up.

In order to prevent damage, turn the circuit off immediately if the fuse on one of the legs of a three-phase circuit blows.

An electric motor changes electrical energy into mechanical energy.

Power factors on motors can be improved by:
1. changing the motor loading
2. changing the motor type
3. using capacitors

Routing cleaning of pump motors includes:
1. checking alignment and balance
2. checking brushes
3. removing dirt and moisture
4. removal of obstructions that prevent air circulation

Cool air extends the useful life of motors.

A motor (electrical or internal combustion) used to drive a pump is called a prime mover.

The speed at which the magnetic field rotates is called the motor synchronous speed and is expressed in rpm.

If a variable speed belt drive is not to be used for 30 days or more, shift the unit to minimum speed setting.

Emory cloth should not be used on electric motor components because it is electrically conductive and may contaminate parts.

Ohmmeters used to test a fuse in a motor starter circuit.

The most likely cause of a three-phase motor not coming to speed after starting – the motor has lost power to one or more phases.

Transformer Facts

Transformers are used to convert high voltage to low voltage.

High voltage is 440 volts or higher.

Standby engines should be run weekly to ensure that it is working properly.

Relays are used to protect electric motors.

Pump and Motor Review Questions

1. Leakage of water around the packing on a centrifugal pump is important because it acts as a (n):
   a. Adhesive
   b. Lubricant
   c. Absorbent
   d. Backflow preventer

2. What is the purpose of wear rings in a pump?
   a. Hold the shaft in place
   b. Hold the impeller in place
   c. Control amount of water leaking from discharge to suction side
   d. Prevent oil from getting into the casing of the pump

3. Which of the following does a lantern ring accomplish?
   a. Lubricates the packing
   b. Helps keep air from entering the pump
   c. Both (a.) and (b.)

4. Closed, open and semi-open are types of what pump part?
   a. Impeller
   b. Shaft sleeve
   c. Casing
   d. Coupling

5. When tightening the packing on a centrifugal pump, which of the following applies?
   a. Tighten hand tight, never use a wrench
   b. Tighten to 20 foot pounds of pressure
   c. Tighten slowly, over a period of several hours
   d. Tighten until no leakage can be seen from the shaft

6. Excessive vibrations in a pump can be caused by:
   a. Bearing failure
   b. Damage to the impeller
   c. Misalignment of the pump shaft and motor
   d. All of the above

7. What component can be installed on a pump to hold the prime?
   a. Toe valve
   b. Foot valve
   c. Prime valve
   d. Casing valve

8. The operating temperature of a mechanical seal should not exceed:
   a. 60°C
   b. 150°F
   c. 160°F
   d. 71°C
   e. c and d

9. What is the term for the condition where small bubbles of vapor form and explode against the impeller, causing a pinging sound?
   a. Corrosion
   b. Cavitation
   c. Aeration
   d. Combustion

10. The first thing that should be done before any work is begun on a pump or electrical motor is:
    a. Notify the state
    b. Put on safety goggles
    c. Lock out the power source and tag it
    d. Have a competent person to supervise the work

11. Under what operating condition do electric motors pull the most current?
    a. At start up
    b. At full operating speed
    c. At shut down
    d. When locked out

12. Positive displacement pumps are rarely used for water distribution because:
    a. They require too much maintenance
    b. They are no longer manufactured
    c. They require constant observation
    d. Centrifugal pumps are much more efficient

13. Another name for double-suction pump is
    a. Double-jet pump
    b. Reciprocating pump
    c. Horizontal split-case pump
    d. Double-displacement pump

14. As the impeller on a pump becomes worn, the pump efficiency will:
    a. Decrease
    b. Increase
    c. Stay the same

15. How do the two basic parts of a velocity pump operate?

16. What are two designs used to change high velocity to high pressure in a pump?

17. In what type of pump are centrifugal force and the lifting action of the impeller vanes combined to develop the total dynamic head?

18. Identify one unique safety advantage that velocity pumps have over positive-displacement pumps.

19. What is the multistage centrifugal pump? What effects does the design have on discharge pressure and flow volume?

20. What are two types of vertical turbine pump, as distinguished by pump and motor arrangement, which are commonly used to pump ground water from wells?

21. What type of vertical turbine pump is commonly used as an inline booster pump?

22. Describe the two main parts of a jet pump.

23. What is the most common used of positive-displacement pumps in water plants today?

24. What is the purpose of the foot valve on a centrifugal pump?

25. How is the casing of a double-suction pump disassembled?

26. What is the function of wear rings in centrifugal pumps of the closed-impeller design? What is the function of the lantern rings?

27. Describe the two common types of seals used to control leakage between the pump shaft and the casing.

28. What feature distinguishes a close-coupled pump and motor?

29. What is the value of listening to a pump or laying a hand on the unit as it operates?

30. Define the term “racking” as applied to pump and motor control.

31. When do most electric motors take the most current?

32. What are three major ways of reducing power costs where electric motors are used?

33. What effect could over lubrication of motor bearings have?

34. Why should emery cloth not be used around electrical machines?

35. What are the most likely causes of vibration in an existing pump installation?

36. What can happen when a fuse blows on a single leg of a three-phase circuit?

37. Name at least three common fuels for internal-combustion engines.

38. List the type of information that should be recorded on a basic data card for pumping equipment.

39. What is the first rule of safety when repairing electrical devices?

Answers:

1. B
2. C
3. C
4. A
5. C
6. D
7. B
8. E
9. B
10. C
11. A
12. D
13. C
14. A
15. A spinning impeller accelerates water to a high velocity within a casing, which changes the high-velocity, low-pressure water to a low-velocity, high-pressure discharge.
16. Volute casing and diffuser vanes.
17. Mixed-flow pump (the design used for most vertical turbine pumps)
18. If a valve is closed in the discharge line, the pump impeller can continue to rotate for a time without pumping water or damaging the pump.
19. A multistage centrifugal pump is made up of a series of impellers and casings (housings) arranged in layers, or stages. This increases the pressure at the discharge outlet, but does not increase flow volume.
20. Shaft-type and submersible-type vertical turbines.
21. A close-coupled vertical turbine with an integral sump or pot.
22. The jet pump consists of a centrifugal pump at the ground surface and an ejector nozzle below the water level.
23. Positive-displacement pumps are generally used in water plants to feed chemical into the water supply.
24. The foot valve prevents water from draining when the pump is stopped, so the pump will be primed when restarted.
25. The bolts holding the two halves of the casing together are removed and the top half is lifted off.
26. Wear rings prevent excessive circulation of water between the impeller discharge and suction area. Lantern rings allow sealing water to be fed into the stuffing box.
27. (1) Packing rings are made of graphite-impregnated cotton, flax, or synthetic materials. They are inserted in the stuffing box and held snuggly against the shaft by an adjustable packing gland. (2) Mechanical seals consist of two machined and polished surfaces. One is attached to the shaft, the other to the casing. Spring pressure maintains contact between the two surfaces.
28. The pump impeller is mounted directly on the shaft of the motor.
29. An experienced operator can often detect unusual vibration by simply listening or touching. Vibration, especially changes in vibration level, are viewed as symptoms or indicators of other underlying problems in foundation, alignment and/or pump wear.
30. Racking refers to erratic operation that may result from pressure surges when the pump starts; it is often a problem when the pressure sensor for the pump control is located too close to the pump station.
31. During start-up.
32. (1) Increase system efficiency; (2) spread the pumping load more evenly throughout the day; (3) reduce power-factor charges
33. The bearings may run hot, and excess grease or oil could run out and reach the motor windings, causing the insulation to deteriorate.
34. The abrasive material on emery cloth is electrically conductive and could contaminate electrical components.
35. Imbalance of the rotating elements, bad bearings and misalignment
36. A condition called single-phasing can occur, causing the motor windings to overheat and eventually fail.

37. gasoline, propane, methane, natural gas and diesel oil (diesel fuel)
38. make, model, capacity, type, date and location installed, and other information for both the driver (motor) and the driven unit (pump)
39. Make sure the power to the device is disconnected. This is critical since rubber gloves, insulated tools and other protective gear are not guarantees against electrical shock.

Section 11

Disinfection

Disinfection

Water Treatment Process That Destroys Pathogens

1

Objectives

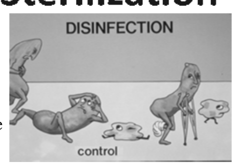
- Principles and methods of disinfecting drinking water
- Chemistry of disinfection
- Application points of disinfectants
- Regulations regarding disinfection
- Operating and control tests

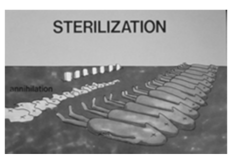
2

Disinfection vs. Sterilization

- <u>Disinfection</u> – the destruction of **pathogenic organisms**
  - To prevent waterborne disease outbreaks
  - Destroys only disease-causing organisms
- <u>Sterilization</u> – the destruction of **all organisms** in the water

  Not all microorganisms are bad!





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Destroying Pathogens in Water

- Some pathogens can survive long enough in water to cause disease outbreaks
- Some pathogens form cysts and become inactive
  - Survive longer

4

Organism Removal

- Occurs by
  - Coagulation
  - Flocculation
  - Sedimentation
  - Filtration

5

Detecting Pathogens in Water

- Coliform bacteria analysis is required for water systems to determine the presence or absence (P/A) of fecal contaminants in the distribution system
- This test does not indicate P/A of other pathogens
  - i.e. *Cryptosporidium*, viruses

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Methods of Disinfection

Pathogen Destruction

Heat Treatment | **Radiation Treatment** | **Chemical Treatment**

7

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Methods of Disinfection

Heat Treatment

- Boiling water in emergency
- "Boil order" may be issued
- Rolling boil for 5 minutes
- Only practical for small amounts of water

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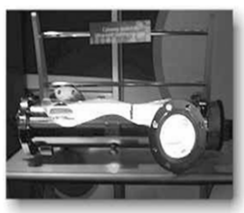
Methods of Disinfection

Radiation

- UV lamps (UV disinfection)
- Requires relatively clear water
- Water must pass close to a lamp
- Lack of residual



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Methods of Disinfection

Chemical Treatment

- Chemical Oxidants
  - Bromine
  - Ozone
  - Chlorine dioxide
  - Miox
  - Chlorine Liquid

Iodine

Potassium permanganate

Chlorine gas

Hypochlorite

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Methods of Disinfection

Bromine (Br_2)

- Dark, reddish-brown liquid
- Vaporizes at room temperature
- Suffocating odor, irritating to eyes, nose & throat
- Causes painful burns if splashed on skin and slow to heal
- Corrosive to metal
- Residual is as effective as chlorine, but not as stable
- Must be added in larger quantities than chlorine
- High cost

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Methods of Disinfection

Iodine (I_2)

- Blue-back solid, violet vapor
- Chlorine-like odor
- Good for emergencies, used at campgrounds
- Can be used in saturator type feeders
- Not recommended for long term consumption

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Methods of Disinfection

Ozone (O_3)

Advantages

- Powerful disinfectant
- Produces no THM's
- Works well for color, taste, and odor control
- Aids in coagulation

Disadvantages

- Must be manufactured on-site
- Bluish, toxic gas with pungent odor
- Extremely unstable
- Leaves no residual, limited by solubility
- Requires large amounts of energy to generate

13

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Methods of Disinfection

Potassium Permanganate ($KMnO_4$)

- Good oxidant
- Mainly used for taste & odor, iron & manganese, & hydrogen sulfide
- Can also be used to control zebra mussels, algae, and reduce coliforms
- Does not produce THM's
- Not registered with USEPA as a disinfectant

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Methods of Disinfection

Chlorine Dioxide (ClO_2)

Advantages

- Powerful oxidant
  - oxidizes Fe and Mn
- Removes color
- Lowers THM formation potential
- Effective at higher pH than chlorine

Disadvantages

- Formed from chlorine gas (Cl_2) and sodium chlorite ($NaClO_2$)
- Strict feed guidelines
- Taste problems may occur
- Some chlorate and chlorite is formed during ClO_2 formation, which can cause adverse health effects

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Methods of Disinfection

Miox

- Mixed oxidant
- 70% hypochlorite, 4% ozone, 2% chlorine dioxide, 2% H_2O_2, 20% other oxidants
- Produces Oxidants electrolytically from a brine solution
- Hydrogen gas is a by-product

Advantages

- Power oxidant
  - reduces taste & odor
- Lower THM formation potential than chlorine gas
- Inactivates *Cryptosporidium* and *Giardia*
- Combined oxidants are faster, more effective than single oxidants

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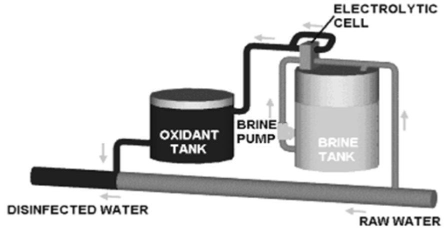
Methods of Disinfection

Miox



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Methods of Disinfection

Chlorine

- Most commonly used disinfectant in U.S.
- Maintains residual
- Chlorine gas, Cl_2
- Calcium hypochlorite (HTH), $Ca(OCl)_2$
- Sodium hypochlorite (bleach), $NaOCl$

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Chlorine

History

- 1774 – first discovered
- 1854 – wastewater treatment in England
- 1896 – Cl_2 gas was used in Louisville, KY
- 1909 – compressed gas cylinder
- 1924 – chlorine institute founded
- 1940 – free residual testing began
- 1944 – chlorine dioxide used at Niagara Falls for taste & odor
- 1992 – Peru halts chlorinization of drinking water

Miox appeared in late 90's

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Chlorine

Chlorine Gas (Cl_2)

- 100% pure
- 2.5 times as dense as air
- Pungent, noxious odor
- Greenish-yellow color
- Highly irritating to eyes, nasal passages, and respiratory tract

20

Chlorine

Chlorine Liquid

- Created by compressing chlorine gas
- Amber color
- 1.5 times as dense as water
- Expands easily into gas at room temperature 460 times

21

Chlorine

Hypochlorite (Liquid)

- Sodiuim hypochlorite (NaOCl)
- Bleach
- Clear, light-yellow color
- Costs 3 times as much as chlorine gas
- Shelf life of 60-90 days
  - 5.25% chlorine Clorox
    to
  - 12.5% chlorine Pool bleach

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Chlorine

Hypochlorite (Solid)

- Calcium hypochlorite [$Ca(OCl)_2$]
- Solid, granular or tablet
- White or yellow-white in color
- Most dangerous – fire hazard
- 65% pure – High Test Hypochlorite (HTH)

23

Chlorine

Containers

150 lb cylinder

- 42 lb/day against water pressure 35 psig @ 70°F
- protective hood & valve covers
- 80-85% liquid volume
- 1 valve
- 1 fusible plug

1 ton cylinder

- max 400 lb/day at 35 psig @ 70°F
- 80-85% liquid volume
- protective shipping hood
- 2 valves
- 6 fusible plugs
- pressure tested @ 5yr intervals

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Chlorination

Chemistry of Chlorination

$Cl_2 + H_2O \rightarrow HOCl + HCl$

hypochlorous acid, hydrochloric acid

- Hypochlorous acid
  - Most effective disinfectant
  - Prevalent at pH less than 7

    Dissociates at higher pH:

    $HOCl \rightarrow H^+ + OCl^-$
  - Hypochlorite ion is only 1% as effective as hypochlorous acid

Chlorination

Chemistry of Hypochlorination

$NaCl + H_2O \rightarrow HOCl + NaOH$

hypochlorous acid

- Sodium hypochlorite will slightly raise the pH because of the sodium hydroxide (NaOH)

Chlorination

Chemistry of Chlorination

- Chlorine reacts with reducing agents in the water
  - Organic matter
  - Iron and manganese
  - Nitrites
- No free residual will be formed until all reducing agents are destroyed
- Chlorine also reacts with ammonia and organics to form combined residuals
- These are not as effective as free residual

Chlorination

Residual Formation

- The *breakpoint* is the point at which the chlorine dosage has met the demand
- Any additional chlorine will result in a free residual

Chlorination

Chlorine Demand

- The difference between the chlorine added to the water and the amount of residual chlorine remaining after a give time

Dose = Demand + Residual

Chlorination

Principles

- Five factors important to success of chlorination
  - Chlorine concentration (C)
  - Contact time (T)

    most important
  - Water temperature
  - Water pH
  - Foreign substances in water

Disinfection

"kill" is proportional to C x T

- Destruction of organisms depends on the concentration of chlorine added (C) and the amount of time the chlorine is in contact with the organisms (T)
- Inversely proportional
  - If one is decreased, the other must be increased to ensure that "kill" remains the same

31

Disinfection

Interferences

- Chlorine is only effective if it comes in direct contact with organisms
- Turbidity protects pathogens from chlorine
- Substances such as ammonia and organic matter reduce effectiveness of chlorine

32

Disinfection

Chlorimination

- Chloramine formed when ammonia reacts with chlorine
- Effective against taste & odor problems
- Can reduce THM level
- Weaker disinfectant than free chlorine
- Usually feed ammonia downstream of chlorine to allow contact time with free Cl_2
- Higher residual or longer contact time required
- Hospital and kidney dialysis centers should be notified if changing to chloramine disinfection

33

Disinfection

Chloramines

$$NH_3 + HOCl \rightarrow \underset{\text{monochloramine}}{NH_2Cl} + H_2O$$

$$NH_2Cl + HOCl \rightarrow \underset{\text{dichloramine}}{NHCl_2} + H_2O$$

$$NHCl_2 + HOCl \rightarrow \underset{\text{trichloramine}}{NCl_3} + H_2O$$

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Disinfection

Application Points

- Pre-chlorination (*source water chlorination*)
  - Begins process of killing or inactivating pathogens
  - Minimizes biological growth throughout process
  - Oxidizes minerals, gases, organics, etc.
  - Increases contact time
  - May improve coagulation
  - High potential for DBP production

35

Disinfection

Application Points

- Post-chlorination (*terminal disinfection*)
  - Application of chlorine to treated water
  - Required to meet state and federal requirements for residual
  - Applied at or immediately before clearwell
  - Clearwell must minimize short circuiting to meet C x T values

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Disinfection

Application Points

- Distribution system
  - Some systems may require booster chlorination
  - Added at storage tank discharge
- Additional application points
  - Feeding 2 or more types of disinfectants at different points may help meet requirements
  - Oxidants other than chlorine can be used early in treatment process to reduce DBPs

37

Disinfection

Application Points

- Groundwater systems
  - Often require no treatment other than chlorination
  - Apply chlorine just past wellhead
  - Hypochlorite most commonly used

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Regulations - SWTR

- Surface Water Treatment Rule (1989)
  - Applies to all surface water plants and groundwater plants under the influence of surface water (GWUI)
- Purpose
  - To protect public from waterborne disease outbreaks
- Goal
  - Removal or inactivation of all disease-causing pathogens
- Requires operating and monitoring with best available technology, disinfection, and filtration

39

Regulations - SWTR

- Most surface and GWUI plants must provide filtration and disinfection to meet treatment techniques
- Turbidity requirements
  - Must not exceed 0.3 NTU in 95% of samples
  - No sample exceeding 5 NTU
- For systems serving 3300 or more people
  - Disinfectant residual must be monitored constantly & must not be below 0.2 mg/L for more than 4 hrs

40

Regulations - SWTR

- Disinfectant residual
  - Must be measured at coliform sampling points
  - Must not be undetectable in more that 5% of samples each month for 2 consecutive months
- Total coliform rule
  - December 31, 1990, new coliform P/A became effective
  - If a routine sample is coliform positive, it must be tested for presence of fecal or E. coli

41

Chlororganics

Organic material + Cl_2 = trihalomethanes (THMs)

- Organics found in all surface and groundwaters
- Humic and fulvic acids from decomposing plant material
- THMs are potential carcinogens

42

Trihalomethane Limits

- Current MCL for total THM = 0.08 mg/L
- Applies to community water systems
- Population 10,000+
- Adds a disinfectant (chlorine)
- Preferred method of controlling THMs is to prevent the formation
- Microbiological safety of the water must not be compromised

Other Disinfection By-products

- Disinfection by-products other than THMs can be formed by chlorine
- Other disinfectants produce by-products
- The Enhanced SWTR addresses some of these
  - Others are still being studied

Disinfection Control Tests

- Chlorine residual
  - Presence of residual
  - Free or combined
  - Concentration
  - By amperometric titration (most accurate, not affected by color or turbidity) or DPD method
- Bacteriological test
  - Indicates fecal contamination
  - Coliforms are more resistant to chlorine than other fecal bacteria
  - If coliforms are not present, other fecals will not be present either

Design Criteria

- Chlorine is still the preferred disinfectant
- Continuous disinfection is required for all community public water systems serving more that 50 connections or 150 people

Design Criteria

- Minimum 2 cylinders
- Chlorinator located in separate room
- 4.4.1.b – Chlorinator capacity shall produce a free chlorine residual of at least 2 mg/L in water after a contact time of at least 30 min when maximum flow rate coincides with max chlorine demand
- 4.4.1.c – Two chlorinators shall be provided and operated simultaneously such that each feed approximately half the chlorine required

Design Criteria

Chlorine Safety

- A fusible plug, designed to melt at 158°F to 165°F, is located in the valve on a 150-lb cylinder and on the head of a ton container
- It is designed to relieve pressure in the cylinder or container when exposed to high heat

Design Criteria

- 4.4.1.d – Spare parts shall be provided
- 4.4.1.e – Automatic switch over unit or low pressure cutoff switch
- 4.4.2.d – 30 minute contact time for groundwater and 2 hour for surface water
- 4.4.3.c – Backflow prevention for vacuum systems will be provided
- 5.3.5.c – Switches for fans and lights outside cylinder room

Design Criteria

- 5.3.4.c – Provided with doors opening outward with a crash bar, assuring ready means of exit; door opening to the building exterior only shall be provided
- 5.3.6 – Rooms heated to 60ºF
- 5.4.c – Respirator and Self Contained Breathing Apparatus (SCBA)
- 5.4.d – Ammonium hydroxide on hand to test for leaks
- 5.4.e – Repair kits on hand, A or B

Design Criteria

- 5.3.5 – Where chlorine gas is used, ventilation for each room shall be provided for one complete air change per minute
- 5.3.5.a – The air outlet from the room shall be near the floor and the point of discharge shall be so located as not to contaminate air inlets to any rooms or structures, or adversely affect the surrounding environment
- 5.3.5.b – Air inlets shall be through louvers near the ceiling, and temperature controlled to prevent adverse affect on chlorinator

Chlorine

Chlorine Gas Containers - 3 types

- 150 lb cylinder
  - Holds 150 lbs of Cl_2
  - Filled weight
    - cylinder + chlorine = 250 lbs
  - Emergency repair kit A is required

Chlorine

Chlorine Gas Containers - 3 types

- Ton cylinders
  - Holds 2,000 lbs Cl_2
  - Filled weight
    - gas + container = 3,700 lbs
  - Emergency repair kit B is required

Chlorine

Chlorine Gas Containers – 3 types

- Tank rail cars and tank trucks
  - Amount varies, around 6,000 lbs
  - Emergency repair kit C is required

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Chlorine

- 3 Things You Must Have If You Use Chlorine Gas
  1. SCBA – self contained breathing apparatus
  2. Chlorine detectors
  3. Emergency repair kit (A, B, or C)

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Chlorine

Safety Requirements

- PPE – personal protective equipment
- 2 in 2 out
  - required for emergencies
  - DO NOT BE A HERO
- Know the SOP and HAZMAT procedures
- Attend 24 hour response technician course through UT

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Chlorine

Safety

- Keep head higher than leak
- Never put water on a chlorine cylinder
- Fusible plug leaks require special handling or training

Exposure

- 1000 ppm – fatal
- 40-60 ppm for 30-60 min may cause serious injury
- 30 ppm IDLH (Immediately Dangerous to Life or Health)
- 1 ppm is OSHA ceiling
- 0.5 ppm without adverse affects

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Chlorine

Operating Problems

- Leaks
  - Detect with ammonia
  - Leak detector for small leaks
- Stiff container valves
- Sudden drop in residual

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Chlorine

Preventive Maintenance

(1) Replace lead washer every time the container is charged

(2) Clean valve threads with wire brush and wrap threads with Teflon tape, linseed oil and graphite joint compound, linseed oil and white lead, or litharge

(3) Replace all chlorine supply line valves annually

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Chlorine

Corrective Measures

- Increase chlorine levels immediately
- Take samples and identify contaminants
- Check distribution system to locate contaminant source or other causes for drop in residual

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Chlorination:
Demand and Dosage
Dilutions
Substitutions

Disinfection Math

1

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Chlorine

- Chlorine and chlorine compounds are the most commonly used disinfectants for water systems in the U.S.
  - Chlorine, Cl_2
  - Calcium hypochlorite (HTH), $Ca(OCl)_2$
  - Sodium hypochlorite (liquid bleach), NaOCl

2

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Purpose of Chlorination

- Chlorination does not destroy all organisms in the water
- Chlorine only destroys pathogenic, or disease-causing organisms

3

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Formula Booklet

Disinfection formulas are on pages 12-13

4

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Chlorine Demand

- If the chlorine dosage is 4.5 mg/L and the residual is 1.2 mg/L, what is the demand?

Cl_2 demand = Cl_2 dose, mg/L - Cl_2 residual, mg/L

= 4.5 mg/L - 1.2 mg/L

= 3.3 mg/L

5

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Chlorine Dosage

- A water plant treats 12 MGD and wants to treat the water with 4.2 mg/L Cl_2. How many pounds per day will the plant use?

Cl_2, lb/day = (dosage,mg/L)(flow,MGD)(8.34lb/gal)

= (4.2mg/L)(12MGD)(8.34lb/gal)

= 420.3 lb/day

6

Chlorine Dosage

- A water plant treats 3.5 MGD and wants to treat the water with 3.2 mg/L of 65% calcium hypochlorite. How many pounds per day will the plant use?

lb/day = (dosage, mg/L)(flow, MGD)(8.34lb/gal) / (% chemical purity, expressed as decimal)

$$= \frac{(3.2 \text{ mg/L})(3.5 \text{ MGD})(8.34 \text{ lb/gal})}{.65}$$

$$= 143.7 \text{ lb/day}$$

Chlorine Dosage

- A water plant treats 300,000 gallons of water a day and wants to treat the water with 3.8 mg/L of 15% sodium hypochlorite. How many pounds per day will the plant use?

lb/day = (dosage, mg/L)(flow, MGD)(8.34lb/gal) / (% chemical purity, expressed as decimal)

$$= \frac{(3.8 \text{ mg/L})(.3 \text{ MGD})(8.34 \text{lb/gal})}{.15}$$

$$= 63.4 \text{ lbs/day}$$

Chlorine Dosage

- Determine the dosage in mg/L for a plant treating 15 MGD using 440 lbs of Cl_2 gas.

mg/L = (lbs/day)(% available chlorine, as decimal) / (MGD)(8.34 lbs/gal)

$$= \frac{(440 \text{ lbs/day})(1)}{(15 \text{ MGD})(8.34 \text{ lbs/gal})}$$

$$= 3.52 \text{ mg/L}$$

Chlorine Dosage

- Determine the dosage in mg/L for a plant treating 650,000 gpd with 21 gallons 15% hypochlorite.

mg/L = (gallons hypochlorite/day)(% conc. as decimal) / MGD

$$= \frac{(21 \text{ gallons})(.15)}{.65 \text{ MGD}}$$

$$= 4.85 \text{ mg/L}$$

Hypochlorination

- How many pounds of 65% HTH are required to make 10 gallons of 1% solution?

lbs HTH = (% desired conc.)(desired gal)(8.34 lb/gal) / % available HTH

$$= \frac{(.01)(10 \text{ gal})(8.34 \text{ lb/gal})}{.65}$$

$$= 1.28 \text{ lb HTH}$$

Dilutions

- How many gallons of 15% bleach will be required to make 60 gallons of 5% bleach?

gal = (% desired conc., as decimal)(desired vol., gal) / % bleach conc., as decimal

$$= \frac{(.05)(60 \text{ gal})}{.15}$$

$$= 20 \text{ gal}$$

Substitutions

- A water plant has just switched from sodium hypochlorite to chlorine gas. If they used an average of 43 gal/day of 15% sodium hypochlorite, how many pounds per day will they use of Cl_2?

lbs Cl_2 = (% bleach, as decimal)(gal bleach)(8.34 lbs/gal)

= (.15)(43 gal)(8.34 lbs/gal)

= 53.8 lbs Cl_2

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Substitutions

- A water plant has run out of calcium hypochlorite for disinfecting a storage tank. If they needed 75 lbs HTH, how many gallons of 15% NaOCl will they need?

$$\textbf{gal bleach} = \frac{\textbf{(\% HTH, as decimal)(lbs. HTH)}}{\textbf{(\% available bleach)(8.34 lbs/gal)}}$$

$$= \frac{(.65)(75 \text{ lbs.})}{(.15)(8.34 \text{ lbs/gal})}$$

= 39 gallons NaOCl

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Storage Tank Disinfection

- A 500,000 gallon storage tank is disinfected with 50 mg/L using 65% HTH. How many pounds of HTH are required?

$$\textbf{lbs HTH} = \frac{\textbf{(dosage,mg/L)(MG)(8.34 lbs/gal)}}{\textbf{\% HTH}}$$

$$= \frac{(50 \text{ mg/L})(.5\text{MG})(8.34)}{.65}$$

= 320.8 lbs

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Water Main Disinfection

- How many pounds of 65% available HTH will be needed to disinfect a section of pipe 250 feet long and 12 inches in diameter with a dose of 50 mg/L?

volume = $(0.785)(\text{diameter})^2(\text{third dimension})$
= $(0.785)(1 \text{ ft})^2(250 \text{ ft})(7.48 \text{gal/ft}^3)$
= 1466 gal

$$\textbf{lbs} = \frac{\textbf{(dosage, mg/L)(volume, MG)(8.34 lbs/gal)}}{\textbf{\% available, as decimal}}$$

$$= \frac{(50\text{mg/L})(.001466\text{MG})(8.34\text{lbs/gal})}{0.65}$$

= 0.94 lbs HTH

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Approved Methods for Disinfectant Residuals

To comply with provisions of the Surface Water Treatment Rule monitoring under Subpart H of 40 CFR §141.74, public water systems must measure residual disinfectant concentrations with one of the analytical methods in the following table. The methods are contained in the 18th, 19th and 20th editions of *Standard Methods*. (When using the 18th edition, corrections to SM-4500-Cl-E and 4500-Cl-G, and procedures for conducting continuous measurements of chlorine residuals are described in Section IV of *Technical Notes on Drinking Water Methods* (EPA/600/R-94/173) available from National Technical Information Service (NTIS) order number PB95-104766.)

Residual	Methodology	Methods
Free Chlorine	Amperometric Titration	4500-Cl-D
	DPD Ferrous Titrimetric	4500-Cl-F
	DPD Colorimetric	4500-Cl-G
	Syringaldazine (FACTS)	4500-Cl-H
Total Chlorine	Amperometric Titration	4500-Cl-D
	Amperometric Titration (low level measurement)	4500-Cl-E
	DPD Ferrous Titrimetric	4500-Cl-F
	DPD Colorimetric	4500-Cl-G
	Iodometric Electrode	4500-Cl-I
Chlorine Dioxide	Amperometric Titration	4500-ClO_2C
	DPD Method	4500-ClO_2D
	Amperometric Titration	4500-ClO_2E
Ozone	Indigo Method	4500-O_3 B

General Effectiveness of Water Treatment Oxidants

Purpose	Chlorine	Chloramines	Ozone	Chorine Dioxide	Potassium Permanganate	Oxygen
Iron Removal	E	N	E	E	E	E
Manganese Removal*	S	N	E	E	E	N
Sulfide Removal	E	N	S	S	S	E†
Taste-and-odor Control	S	N	E	E	S△	S△
Color Removal	E	N	E	E	S	N
Flocculation Aid	E	N	E	U	S§	N
Trihalomethane formation potential control	N	N	E**	E	S	N
Synthetic Organics Removal	S††,△△	N	S††	S††	S††	N
Biological Growth Control	E	S	N§§	E	S	N

Notes: E = effective, S = somewhat effective, N = not effective, U = unknown

* above pH 7
† by stripping
△ except earthy-musty odor-causing compounds
§ may involve adsorption on MnO_2
** may increase problem at low doses
†† depending on compound
△△ may form chlorinated by-products
§§ except with dual-stage ozonation

Advantages and Disadvantages of Water Treatment Oxidants

Oxidant	Advantages	Disadvantages
Chlorine	Strong oxidant, simple feeding, persistant residual, long history of use	DBP’s, taste and odor problems, influences pH
Chloramines	No THM’s formed, presistant residual, simple feeding, long history of use	Weak oxidant; some TOX (total organic halogens) formed; influences pH; taste, odor and growth problems are possible
Ozone	Strong oxidant, usually no THM’s or TOX’s formed, no taste and odor problems, some biodegradable by-products, little pH effect, coagulant aid	Short half-life, generation on-site required, energy intensive, some biodegradable by-products, complex generation and feeding, corrosive
Chlorine Dioxide	Strong oxidant, relatively persistant residual, no THM’s formed, no pH effect	Formation of TOX, by-products of ClO_3 and ClO_2; onsite generation required, possible hydrocarbon odors
Potassium Permanganate	Easy to feed, no THM formation	Moderately strong oxidant, pink H_20, by-products are unknown, causes precipitation
Oxygen	Simple to feed, no by-products, companion stripping, nontoxic	Weak oxidant, corrosion and scaling

Common Waterborne Diseases

Waterborne Disease	Causative Organism	Source of Organism in Water	Symptom
Gastroenteritis	*Salmonella* (bacteria)	Animal of human feces	Acute diarrhea and vomitting
Typhoid	*Salmonella typhosa* (bacteria)	Human feces	Inflamed intestine, enlarged spleen, high temperature - **FATAL**
Dysentary	*Shigella* (bacteria)	Human feces	Diarrhea - rarely fatal
Cholera	*Vibrio comma* (bacteria)	Human feces	Vomitting, severe diarrhea, rapid dehydration, mineral loss – high mortality
Infectious Hepatitis	Virus	Human feces, shellfish grown in polluted waters	Yellow skin, enlarged liver, abdominal pain – low mortality, lasts up to 4 months
Amoebic Dysentery	*Entamoeba* histolytica (protozoan)	Human feces	Mild diarrhea, chronic dysentery
Giardiasis	*Giardia lamblia* (protozoan)	Animal or human feces	Diarrhea, cramps, nausea and general weakness – not fatal, lasts 1-30 weeks
Crytosporidiosis	*Cryptosporidium* (protozoan)	Human and animal feces	Acute diarrhea, abdominal pain, vomiting and low-grade fever
Legionellosis	*Legionella pneomophila* and related bacteria		Acute respiratory illness

Field Data for Newly Constructed or Repaired Water Distribution Lines

Work Order # ________________________ Project # ______________________

Date: ____________________ Time: ____________________

Location: ____

Type of Main: _____________ Size: ______________ Footage: ____________

Pounds of HTH: ________________

Disinfection procedure utilized: ____

____

Flushing: ____

Comments: ____

____

____

Signature: ___________________________ Date: ______________

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Pipe Disinfection Formulas for <u>50 mg/L</u> of HTH

If a pipe is of size not listed below, the following formula will give the calculations needed to find the amount of HTH needed, if the length of line is given:

Calculation Formula = $0.000026007(X)^2(L)$

L= the length of the line in feet,
X = the diameter in inches

Or, Use the following Chart, if Pipe Diameter is listed

DIAMETER (INCHES)	LBS OF HTH
6	0.000935(L)
8	0.00166(L)
10	0.0026(L)
12	0.00374(L)
14	0.00509(L)
16	0.00665(L)
20	0.01038(L)
C24	0.01495(L)

Contact Shannon Pratt At Fleming Training Center

(615) 898-6506

Disinfection Vocabulary

______1. Breakpoint	______8. Free Residual Chlorine
______2. Chlorination	______9. Organic Substance
______3. Combined Residual	______10. Ozone Generator
______4. C x T Value	______11. Sterilization
______5. Disinfection Residual	______12. Trihalomethane
______6. Disinfection	______13. UV Disinfection
______7. Disinfection By-Product	______14. Waterborne Disease

A. The process of destroying all organisms in water.

B. The product of the residual disinfectant concentration C and the corresponding disinfectant contact time T.

C. The water treatment process that kills disease-causing organisms in water.

D. A device that produces ozone by passing an electrical current through air or oxygen.

E. The point at which the chlorine dose has met the demand.

F. A chemical substance of animal or vegetable origin, having carbon in its molecular structure.

G. Disinfection using ultraviolet light.

H. The process of adding chlorine to water to kill disease-causing organisms.

I. The residual formed after the chlorine demand has been satisfied.

J. An excess of chlorine left in water after treatment. Indicates the adequate amount of disinfectant has been added to ensure complete disinfection.

K. Compound formed when organic substances such as humic and fulvic acids react with chlorine.

L. Chemical compounds that are formed by the reaction of disinfectants with organic compounds in water.

M. The chlorine residual produced by the reaction of chlorine with substances in the water. It is not as effective as free residual.

N. A disease caused by waterborne organisms.

Disinfection Review Questions

1. List four infectious diseases that can be transmitted in water.
    -
    -
    -
    -

2. What are the limitations of UV disinfection?

3. Name the three types of chlorine commonly used in water treatment, and give a short description of each.

4. Define breakpoint.

5. When chlorine is added to water, it breaks down into two products. Name them.

6. Which of these two products (in question 5) is the most effective disinfectant?

7. Why is chlorination less effective at a higher pH?

8. List four processes involved in the Multiple Barrier approach to prevent waterborne disease outbreaks.

9. From a public health standpoint, which is more important – disinfection by-product formation or bacteriological safety of the water?

10. What is the difference between disinfection and sterilization?

11. What is a pathogen?

12. In addition to concentration and contact time, list other factors important to chlorination.

13. Describe the effect of temperature on chlorination.

14. List at least four substances in the water that might affect chlorination.

15. Define chlorine residual.

16. List two types of chlorine residual.

17. What is the practical significance of chlorine residual?

18. Define chlorine demand.

19. List four other uses of chlorine besides disinfection of potable water.

20. List the types of chlorine containers in common use.

21. How much does one full ton container of chlorine weigh?

22. Describe chlorine gas and its health effects.

23. Describe sodium hypochlorite and calcium hypochlorite.

24. Beginning with the chlorine supply, list in order the major components of equipment found in a typical chlorination system.

25. What is the purpose of a weigh scale?

26. What function does the injector serve?

27. While a chlorine tank valve is open, where should the tank-valve wrench be kept?

28. What chemical is used to check for chlorine leaks?

29. What organism is measured to determine the effectiveness of disinfection? Why?

30. Explain the significance of water containing total coliform.

31. Three types of safety equipment are absolutely essential in every installation. What are they?

Answers to Disinfection Vocabulary and Questions

Vocabulary

1. E
2. H
3. M
4. B
5. J
6. C
7. L
8. I
9. F
10. D
11. A
12. K
13. G
14. N

Review Questions

1. Typhoid fever, dysentery, cholera, infectious hepatitis
2. Water must pass very close to the lamp to be disinfected, the water must be very clear; UV leaves no residual.
3. Chlorine gas – greenish-yellow gas; pungent, noxious odor, toxic if inhaled; 2.5 times heavier than air; causes burns on skin and in respiratory tract
   Sodium Hypochlorite – liquid; can cause burns on skin; chlorine-like odor; 5-15% strength
   Calcium Hypochlorite – solid; 65% strength; fire hazard; can cause burns
4. The point at which the chlorine dose has met the demand. Any additional chlorine will result in a residual.
5. Hypochlorous acid (HOCl) and hydrochloric acid (HCl)
6. Hypochlorous acid is the most effective.
7. The hypochlorous acid breaks down into hypochlorite ion, which is only 1% as effective.
8. Watershed protection; filtration; disinfection; education
9. Bacteriological safety
10. Disinfection is the destruction of disease-causing microorganisms; sterilization is the destruction of all microorganisms.
11. A disease-causing microorganism.
12. Temperature, pH, substances in the water
13. Generally, the higher the temperature, the faster the kill.
14. Organic matter, iron, manganese, nitrite, hydrogen sulfide, any material that causes turbidity
15. The measure of the amount of chlorine remaining after the disinfection reaction is complete.
16. free available chlorine residual and combined residual chlorine
17. It is a quick way to evaluate chlorination effectiveness. A residual is evidence that enough chemical was added. In chlorination, practical experience indicates that if a certain chlorine residual is present after a certain period of time, then enough chlorine was added to accomplish disinfection.
18. The measure of the amount of chlorine used up during the chlorination reactions.
19. Disinfection of pipelines and tanks; iron and manganese oxidation; hydrogen sulfide oxidation; taste and odor destruction; algae control; slime control; coagulation aid; filtration aide
20. 100-lb cylinder; 150-lb cylinder; ton container; tank truck; railroad tank car; tank barge
21. About 3700 lbs

22. A greenish-yellow gas about 2.5 times as dense as air; non-explosive; nonflammable; highly irritating to smell; can kill at concentrations as low as 0.1%; very hazardous; turns into a liquid under pressure; Noncorrosive if dry; extremely corrosive when mixed with some moisture
23. $Ca(OCl)_2$, calcium hypochlorite, is a dry, white to yellow-white granular material containing about 65% available chlorine by weight. It is also available in 0.01-lb (5-g.) tablets. Calcium hypochlorite will react with organic materials to generate heat and possibly start a fire; it should be stored accordingly.
    NaOCl, sodium hypochlorite, is a clear, greenish-yellow liquid solution. Common liquid household bleach is an example of a 5% available chlorine solution. Solutions up to 15% are available commercially. There is no storage fire hazard, but the chemical is quite corrosive.
24. Chlorine cylinder or container; weigh scale; auxiliary valve; feed lines; manifold; feed line; chlorinator; injector; solution line; diffuser.
25. The weigh scale is the only accurate means the operator has of knowing exactly how much chlorine is left in the container.
26. The injector is a venturi-like device that creates a vacuum, which pulls the gas through the chlorinator and into the solution water.
27. On the tank valve, so valves may be closed quickly in an emergency.
28. Ammonia
29. Total coliform bacteria, which is excreted with fecal matter. Total coliform bacteria are present in far greater numbers than the pathogens that might be present and are much easier to measure than the pathogens themselves. In addition, they are more resistant to environmental changes then pathogens; so if coliforms are not present, it is assumed pathogens are not present.
30. Total coliform in water indicates that pathogenic organisms might be present.
31. Self-contained breathing apparatus (SCBA); container emergency repair kit; adequate ventilation

Section 12

Storage Tanks

Storage Tanks

Disinfection

Rules and Regulations

Objectives

- Reasons for storing water
- Operating storage and emergency storage
- Size and location for storage tanks
- Operation and maintenance
- Rules and regulations

Water Storage

Purpose

- Equalizing supply and demand
- Increasing operating convenience
- Leveling out pumping requirements
- Decreasing power costs

Water Storage

Purpose

- Providing water during power or pump failure
- Providing adequate water for fire fighting
- Providing surge relief
- Increasing detention times
- Blending water sources
- Decrease pumping costs

Water Storage

Capacity Requirements

- Based on maximum water demands in different parts of the system
- Too much storage can cause stagnant water and taste & odor problems
  - 20 % turnover rate to prevent it from becoming septic
    - less sediment

Water Storage

Type of Service

- Operating storage
  - Tank directly connected to distribution piping
  - Fills and empties based on system pressure
- Emergency storage
  - Used for emergency, i.e. fire protection
  - Not suitable for potable use
  - Subject to freezing due to lack of circulation

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Storage Tanks

- Elevated tanks
- Ground-level reservoirs
- Standpipes
- Hydropneumatic system

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Storage Tanks

Elevated Tanks

- Supported by steel or concrete tower
- Maintains adequate and uniform pressure
- Minimizes variations in pressure due to turning pumps on or off
- May require altitude valve to prevent overflow
  - One-way are best
- More expensive than ground tanks

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Storage Tanks

Standpipes

- Tank rests on ground
  - Has greater height than diameter
- Stores volumes at low pressure
- Water must be turned over frequently to avoid stagnation
  - 20% is bare minimum
- Located at high points in land elevation

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Storage Tanks

Ground-Level Reservoirs

- For raw water - lakes, ponds, basins
- For finished water - ground level or underground tanks
  - Lower initial cost than elevated tank, but requires pumps to move water
  - Main disadvantage is cost of booster pump station that must be used with the tank

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Storage Tanks

Ground-Level Reservoirs

- This is an old open-topped reservoir that has been converted with a liner-cover

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Storage Tanks

Hydropneumatic System

- Partially filled with water; partially filled with compressed air
  - 2/3 water to 1/3 air
- Air helps maintain pressure in tank
- Usually for very small water systems

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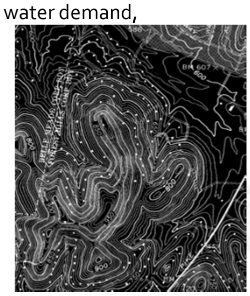
Storage Tanks

Selection and Location of Storage

- Determined by hydraulics, water demand, elevation of terrain, purpose of tank, etc
- Type of storage depends on purpose of tank



Tank Equipment

Monitoring Devices

- Pressure sensor at base of tank
  - Altitude valve
- Level sensor inside tank
- Data transmitted to central location
  - Alarms can alert operator of high or low levels

Tank Equipment

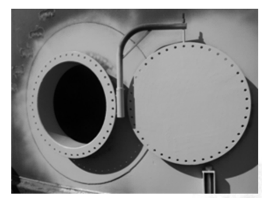
Air Vents

- Allow air to enter and escape as water level rises
- Require screens to keep out birds & other contaminants
- Mesh should be #24 and stainless steel

Tank Equipment

Access Hatches

- For entry and ventilation during maintenance
- Hatch on roof requires rim to prevent runoff from entering tank
- Hatch at bottom of tank must withstand tank pressure
- Must be secured to prevent vandalism
  - Locks must be in place since 9/11

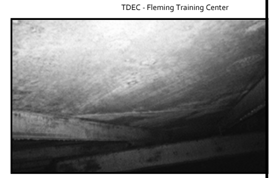


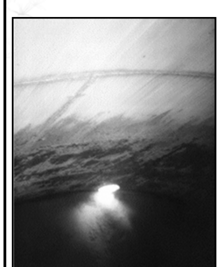
Tank Equipment

Ladders

- Most ladders begin about 8 ft from ground to deter unauthorized use
- May extend to ground if heavy metal shield is locked in place to prevent unauthorized entry
- All ladders must meet OSHA regs, including safety cage

Tank Equipment





Coatings

- Protect interior and exterior of tank from corrosion without causing taste & odor problems
- Coatings must meet the requirements of NSF (ANSI Standard 61)

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Tank Equipment

Cathodic Protection

- Can assist in corrosion control
- Electrodes placed in tank which corrode instead of tank and appurtenances
- Inspect annually

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Maintenance

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Tank Inspections

- Must be professionally inspected every 5 years in accordance with state requirements (Rule 33)
  - Inspection by draining or by using a diver

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Tank Inspections

- Inspection reports must be on file and available for review by State Sanitary Inspectors
- Visual inspections recommended annually

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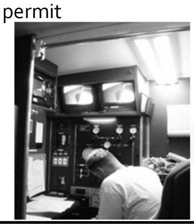
Tank Inspections

- Requires draining the tank or using divers
- Check vents, overflows, paint, altitude valves, etc
- Check for corrosion inside & outside
- Considered confined space; get permit



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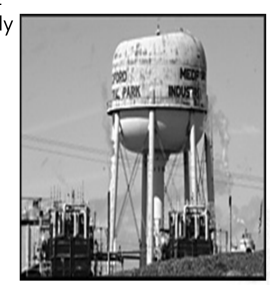
Storage Tank Collapse

- Caused by massive leak in 42 inch water main which quickly drained the tank
  - 50,000 gallons per minute
- Vacuum formed sucking the roof in



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Security

- Fencing, locks on access to manholes and other necessary precautions shall be provided to prevent trespassing, vandalism, and sabotage

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Security

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Records

- Every tank in your system should have a historical record file containing, as a minimum, the most current inspection report
- Location, type of maintenance or repair performed, all contract documents and specifications for repair, paint and equipment submittals, etc

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Storage Tank Safety

- Follow regulations for confined spaces
- Inspect ladders and safety cages for damage
- Use protective equipment
- Provide ventilation inside tank when inspecting
- Provide adequate lighting with proper wiring to prevent shock hazard

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AWWA Standard for Disinfection of Water Storage Facilities

- Before placing into service, all storage tanks shall be disinfected
- There are standards for disinfecting storage tanks covered by ***AWWA C652***
  - Covers materials, tank preparation, disinfectant application and sampling for coliform bacteria

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Chlorine Disinfection

- Liquid chlorine
  - 100% available chlorine
- Sodium hypochlorite
  - 5-15% available chlorine
- Calcium hypochlorite
  - 65% available chlorine

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Methods of Chlorination

Method 1

- Water tank shall be filled to overflow level with enough chlorine added to maintain at least 10ppm residual for 24 hour period

Methods of Chlorination

Method 2

- A solution of 200 ppm available chlorine is applied directly to the entire surface of the storage tank that comes in contact with water when it is full for at least 30 minutes
- Applied by brushing or spraying on
- Tank should be flushed with potable water before put back into service
- WARNING – experienced operators only
  - Hazardous to attempt

Methods of Chlorination

Method 3

- Water and chlorine are added to the storage tank to make a 50 ppm available chlorine that fills about 5% of the total storage volume
- This is held in the tank for no less than 6 hours
- The tank is then filled up to the overflow level and held for at least 24 hours
- There should be a 2 ppm residual chlorine remaining after a 24 hour period
- All highly chlorinated water needs to be drained

Methods of Chlorination

Bacteriological Sampling and Testing

- Storage tanks must be tested for coliform bacteria after chlorination procedure and before it is put back into service
- If positive sample occurs, sampling should be repeated until two consecutive samples are negative
  - If this does not occur, tank must be disinfected again and then tested

Rules and Regulations

- From Community Public Water Systems Design Criteria Division of Water Supply Tennessee Department of Environment and Conservation, 1997; Part 8

Rules and Regulations

- 8.0.2 Protection – All new finished water storage structures shall have suitable watertight roofs or covers which exclude birds, animals, insects, and excessive dust.

Rules and Regulations

- 8.0.3 Protection from Trespassers – Fencing, locks on access to manholes, and other necessary precautions shall be provided to prevent trespassing, vandalism, and sabotage.

Rules and Regulations

- 8.0.4 Drains – No drain on a water storage structure may have a direct connection to sewer or storm drain. Splash pad and drainway shall be provided to prevent erosion.

Rules and Regulations

- 8.0.5 Overflow – The overflow pipe of a water storage structure should be brought down near the ground. No overflow may be connected directly to a sewer or storm drain.
  - c. The overflow shall be protected with a 24 mesh non-corrodible screen with a flap valve.

Rules and Regulations

- 8.0.5 Overflow cont'd

Rules and Regulations

- 8.0.6 Access – Manholes on scuttles above waterlines
  - a. shall be…on ground-level structures manholes should be elevated 24 to 36 inches above the top or covering sod.

Rules and Regulations

- 8.0.7 Vents – Finished water storage structures shall be vented by special vent structures
  - a. shall prevent the entrance of surface water
  - b. shall exclude birds and animals
  - c. shall…be covered with 24-mesh non-corrodible screen cloth.

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Rules and Regulations

- 8.0.10 Safety – Safety shall be considered…
  - a. ladders, ladder guards, balcony railings, and safe location of entrance hatches shall be provided where applicable.

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Rules and Regulations

- 8.0.14 Painting and/or Cathodic Protection – Proper protection should be given to metal surfaces by paints or other protective coatings, by cathodic protective devices, or by both.
  - a. paint systems consistent with AWWA standards, or…all paints must be acceptable to FDA and EPA for contact with potable water
  - b. cathodic protection should be designed and installed by competent technical personnel

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Rules and Regulations

- 8.0.15 Turnover of Water – If the storage reservoir is sized large than required for initial demand and there is more than 2 days storage, provisions shall be made for turnover of the water tank and/or booster chlorinator
- 8.0.17 Disinfection – Finished water storage structures shall be disinfected in accordance with AWWA Standard C652 before being put into service
- 8.2.5 (Pressure Tanks) Auxiliary Power – Auxiliary power with automatic takeover capability shall be provided when positive pressures are not available from system gravity flow

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Rules and Regulations

- 8.0.16 Sampling – A suitable sampling tap should be provided on all storage structures and be protected from public access

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Rules and Regulations

Distribution Storage

- 8.3.1 The purpose of system storage is to have sufficient water available to provide adequate flow and pressure at peak demand as well as to provide for fire flow when needed. For most water systems, a satisfactory rule-of-thumb to meet these needs it to provide at least the average 24-hour demand in elevated storage
- 8.3.4 Level Controls – Adequate controls shall be provided to maintain levels in distribution system storage structures
  - a. telemeter equipment should be used when pressure-type controls are employed and any appreciable head loss occurs in the distribution system
  - b. altitude valves or equivalent controls may be required for a second and subsequent structures on the system

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Ground Storage Tank Inspection Report

Job No.: ______________ Date: ________________ Inspector: ___________________

Tank owner: ____________________________ Owner's order #: _________________

Owner's representative: ________________________ Title: ______________________

Mailing address: ____

Physical address: ____

City, State: ____ Zip: _________________

County tank is located: __________________ Seismic zone of county: ___________

Telephone: _____________________________ Fax: _____________________________

Location of tank: ____

Original Contractor #: _______________________________ Year built: ___________

Original Manufacturer: ______________________________ Capacity: ____________

Date of last inspection: ____

Diameter: _________________________ Height: ___________________________________

Type of construction: Welded: ______________ Riveted: _____________

Who is customer's insurance carrier? ____

Storage Tank Vocabulary

A. Altitude Valve
B. Booster Disinfection
C. Cathodic Protection
D. Elevated Storage
E. Elevated Tank
F. Emergency Storage
G. Ground-level tank
H. Hydropneumatic System
I. Overflow Level
J. Reservoir
K. Riser
L. Standpipe
M. Tank

______1. An electrical system for preventing corrosion to metals, particularly metallic pipes and tanks.
______2. A system using an airtight tank in which air is compressed over water (separated from the air by a flexible diaphragm). The air imparts pressure to water in the tank and the attached distribution pipelines.
______3. A structure used in a water system to contain large volumes of water or other liquids.
______4. The maximum height that water or liquid will rise in a receptacle before it flows over the overflow rim.
______5. A valve that automatically shuts off water flow when the water level in an elevated tank reaches a preset elevation then opens again when the pressure on the system side is less than that on the tank side.
______6. Storage volume reserved for catastrophic situations, such as supply-line break or pump-station failure.
______7. (a) Any tank or basin used for the storage of water. (b) A ground-level storage tank for which the diameter is greater than the height.
______8. A ground-level water storage tank for which the height is greater than the diameter.
______9. In the distribution system, storage of water in a tank whose bottom is at or below the surface of the ground.
______10. In any distribution system, storage of water in a tank supported on a tower above the surface of the ground.
______11. The vertical supply pipe to an elevated tank.
______12. A water distribution storage tank that is raised above the ground and supported by posts or columns.
______13. The practice of adding additional disinfectant in the distribution system.

Storage Tank Review Questions

1. List 9 reasons for providing water storage in a distribution system.
   -
   -
   -
   -
   -
   -
   -
   -
   -

2. List the 4 types of distribution storage tanks and a description of each.
   -
   -
   -
   -

3. What is the difference between operating storage and emergency storage?

4. Why should vent openings on storage tanks be screened?

5. What is the purpose of an altitude valve?

6. How often must storage tanks be inspected according to the Regulations for Public Water Systems and Drinking Water Quality for the State of Tennessee?

7. After disinfection, what must be done before a tank is put back in service?

8. Name four things that should be considered when determining the type and the site for a new storage tank.
   -
   -
   -
   -

9. Why should the overflow pipe on a storage tank never be directly connected to a sewer or storm drain?

10. How are storage tanks protected from corrosion?

Storage Tank Review Questions

1.
   - Equalizing pressure and demand
   - Increasing operating convenience
   - Leveling out pumping requirements
   - Decreasing power costs
   - Providing water during source or power failure
   - Providing adequate water for fire fighting
   - Providing surge relief
   - Increasing detention time
   - Blending water source

2.
   - Elevated – tank on tower, provides pressure, minimizes pressure variations
   - Standpipe – tank on ground, taller than diameter, stores large volumes of water at low pressure, safer than elevated tank, may require pump
   - Ground-level reservoir – diameter greater than height, requires pump
   - Hydro-pneumatic – 2/3 water, 1/3 air; air helps maintain pressure, usually used with wells; small tanks

3. Emergency storage is not considered to be potable water – for emergencies only, e.g. fire protection.
   Operating storage is directly connected to distribution system, fills and empties by distribution pressure.

4. To keep out birds, insects, animals, etc.

5. To keep tank from overflowing

6. Professionally every 5 years

7. Bacteriological samples must be taken and must pass.

8. Water demand; Hydraulics, terrain; Purpose of tank; Public opinion

9. That would be a cross connection

10. Cathodic protection, coatings

Storage Tank Vocabulary

1. C
2. H
3. M
4. I
5. A
6. F
7. J
8. L
9. G
10. D
11. K
12. E
13. B

Section 13

Rules and Regs

RULES
OF
TENNESSEE DEPARTMENT OF ENVIRONMENT AND CONSERVATION
BUREAU OF ENVIRONMENT
DIVISION OF WATER SUPPLY

CHAPTER 1200-05-01
PUBLIC WATER SYSTEMS

TABLE OF CONTENTS

1200-05-01-.01 AUTHORITY.

(1) These Rules and Regulations are issued under the authority of Public Acts of 1983, Chapter 324.

(2) The Division of Water Supply is responsible for the supervision of public water systems.

Authority: *T.C.A. §§ 4-5-201 et seq. and 68-221-701 et seq.* ***Administrative History:*** *Original rule certified June 7, 1974. Repeal and new rule filed June 30, 1977; effective August 1, 1977. Amendment filed February 3, 1984; effective February 12, 1985. Amendment filed September 26, 1988; effective November 10, 1988.*

1200-05-01-.02 PURPOSE.

(1) The purpose of these Rules and Regulations is to provide guidelines for the interpretation of §*68-221-701 et seq*. of the *Tennessee Code Annotated* and to set out the procedures to be followed by the Department in carrying out the State's primary enforcement responsibility under the Federal Safe Drinking Water Act. These Rules and Regulations set out the requirements which agents, employees or representatives of public water systems must meet in the following areas: in the preparation and submission of plan documents for public water systems; in the supervision of all phases of construction; in supplying safe drinking water meeting all applicable maximum contaminant levels or treatment technique requirements; in

(Rule 1200-05-01-.02, continued)

providing adequate operation and maintenance of the system; and in complying with procedural requirements for appealing orders issued by the Commissioner of the Tennessee Department of Health and Environment against a public water system.

(2) Where the terms *shall* and *must* are used, practice and usage is sufficiently standardized to indicate a *mandatory requirement*, insofar as any complaint action by the Department is concerned. Other items, such as *should, recommend, preferred*, and the like, indicate *desirable procedures* or *methods*.

Authority: *T.C.A. §§4-5-201 et seq., 4-5-202, and 68-221-701 et seq.* ***Administrative History:*** *Original rule certified June 7, 1974. Repeal and new rule filed June 30, 1977; effective August 1, 1977.*

1200-05-01-.03 SCOPE.

These rules will apply to all public water supply systems that provide water for human consumption through pipes or other constructed conveyances, if such system has at least fifteen (15) service connections or regularly serves an average of at least twenty–five (25) individuals daily at least sixty (60) days out of the year. A public water supply system is either a community water system or a non–community water system. A community water system is a public water supply system which serves at least fifteen (15) service connections used by year-round residents or regularly serves at least twenty–five (25) year–round residents. A non–community water system is a public water supply system that is not a community water system and which generally serves a transient population such as hotels, motels, restaurants, camps, service stations churches, industry, etc. A Non-Transient Non–Community Water System is a non–community water system that regularly serves at least 25 of the same persons over six (6) months per year. These rules do not apply to public water systems which meet all of the following criteria:

(1) consists only of distribution and storage facilities (and does not have any collection and treatment facilities);

(2) obtains all of its water from, but is not owned or operated by, a public water system to which such regulations apply;

(3) does not sell water to any person; and

(4) is not a carrier which conveys passengers in interstate commerce.

Authority: *T.C.A. §§4-5-202, 68-221-701 et seq., and 68-221-704.* ***Administrative History:*** *Original rule certified June 7, 1974. Repeal and new rule filed June 30, 1977; effective August 1, 1977. Amendment filed February 3, 1984; effective February 12, 1985. Amendment filed September 26, 1988; effective November 10, 1988. Repeal and new rule filed August 15, 2005; effective October 29, 2005.*

1200-05-01-.04 DEFINITIONS.

(1) "Action level" is the concentration of lead or copper in water which may determine the treatment requirements that a water system is required to complete.

(2) “Bag Filters” are pressure-driven separation devices that remove particulate matter larger than 1 micrometer using an engineered porous filtration media. They are typically constructed on a non-rigid fabric filtration media housed in a pressure vessel in which the direction of flow is from the inside of the bag to outside.

(3) “Bank Filtration” is a water treatment process that uses a well to recover surface water that has naturally infiltrated into ground water through a river bed or bank(s). Infiltration is typically enhanced by the hydraulic gradient imposed by nearby pumping water supply or other wells.

(Rule 1200-05-01-.04, continued)

(4) "Benchmark" A disinfection benchmark is the lowest monthly average value of the monthly logs of *Garidia Lamblia* inactivation.

(5) "Business Plan" means a document which identifies source(s) of income or revenue sufficient to meet expenses over a three (3) year period. The business plan will identify costs related to retaining a certified operator, estimated annual infrastructure repair costs, depreciation, facility maintenance fees, estimated annual monitoring costs, estimated costs of providing public notices, estimated administrative costs, and any and all other operational, treatment, and related costs (e.g. chemicals and other supplies used to treat water, etc.). The business plan must include the re-payment of borrowed and amortized funds.

(6) "Capacity Development Plan" means a document(s) identifying what actions a public water system is taking or shall take to become a "viable water system." Such plan shall include information concerning retention of a Certified Operator in direct charge; system ownership and accountability; staffing and organizational structure; fiscal management and controls, source water assessment and protection plan; "business plan;" and any and all other information identifying any further action that shall be taken.

(7) "Cartridge filters" are pressure-driven separation devices that remove particulate matter larger than 1 micrometer using an engineered porous filtration media. They are typically constructed a rigid or semi-rigid self-supporting filter elements housed in pressure vessels in which flow is from the outside of the cartridge to the inside.

(8) "Coagulation" means a process using coagulant chemicals and mixing by which colloidal and suspended materials are destabilized and agglomerated into flocs.

(9) "Combined distribution system" is the interconnected distribution system consisting of the distribution systems of wholesale systems and of the consecutive systems that receive finished water.

(10) "Community Water System" means a public water system which serves at least fifteen (15) service connections used by year-round residents or regularly serves at least twenty-five (25) year-round residents.

(11) "Compliance cycle" means the nine-year calendar year cycle during which public water systems must monitor for certain contaminants. Each compliance cycle consists of three three-year compliance periods. The first calendar year cycle begins January 1, 1993 and ends December 31, 2001; the second begins January 1, 2002 and ends December 31, 2010; the third begins January 1, 2011 and ends December 31, 2019.

(12) "Compliance period" means a three year calendar year period within a compliance cycle. Each compliance cycle has three three-year compliance periods. Within the first compliance cycle, the first compliance period runs from January 1, 1993 to December 31, 1995; the second from January 1, 1996 to December 31, 1998; the third from January 1, 1999 to December 31, 2001.

(13) "Comprehensive performance evaluation (CPE)" is a thorough review and analysis of a treatment plant's performance-based capabilities and associated administrative, operation and maintenance practices. It is conducted to identify factors that may be adversely impacting a plant's capability to achieve compliance and emphasizes approaches that can be implemented without significant capital improvements. For purposes of compliance, the comprehensive performance evaluation must consist of at least the following components: assessment of plant performance; evaluation of major unit processes; identification and

(Rule 1200-05-01-.04, continued)

prioritization of performance limiting factors; assessment of the applicability of comprehensive technical assistance; and preparation of a CPE report.

(14) "Confluent growth" means a continuous bacterial growth covering the entire filtration area of a membrane filter, or a portion thereof, in which bacterial colonies are not discrete.

(15) "Connection" means the point at which there is a meter or service tap if no meter is present.

(16) “Consecutive system is a public water system that receives some or all of its finished water from one or more wholesale systems. Delivery may be through a direct connection or through the distribution system of one or more consecutive systems.

(17) "Contaminant" means any physical, chemical, biological, or radiological substance or matter in water.

(18) "Conventional filtration treatment" means a series of processes including coagulation, flocculation, sedimentation, and filtration resulting in substantial particulate removal.

(19) "Corrosion inhibitor" means a substance capable of reducing the corrosivity of water toward metal plumbing materials, especially lead and copper, by forming a protective film on the interior surface of those materials.

(20) "CT" or "CTcalc" is the product of "residual disinfectant concentration" (C) in mg/1 determined before or at the first customer, and the corresponding "disinfectant contact time" (T) in minutes, i.e., "C" x "T". If a public water system applies disinfectants at more than one point prior to the first customer, it must determine the CT of each disinfectant sequence before or at the first customer to determine the total percent inactivation or "total inactivation ratio". In determining the total inactivation ratio, the public water system must determine the residual disinfectant concentration of each disinfection sequence and corresponding contact time before any subsequent disinfection application point(s). "$CT_{99.9}$" is the CT value required for 99.9 percent (3-log) inactivation of Giardia lamblia cysts. $CT_{99.9}$ for a variety of disinfectants and conditions appear in Tables 1.1-1.6, 2.1, and 3.1 of 1200-05-01-.31(5)(b)3.

$$\frac{CTcalc}{CT_{99.9}}$$

is the inactivation ratio. The sum of the inactivation ratios, or total inactivation ratio shown as

$$\Sigma \quad \frac{(CTcalc)}{(CT_{99.9})}$$

is calculated by adding together the inactivation ratio for each disinfection sequence. A total inactivation ratio equal to or greater than 1.0 is assumed to provide a 3-log inactivation of Giardia lamblia cyst. Disinfectant concentrations must be determined by tracer studies or an equivalent demonstration approved by the Department.

(21) "Department" when used in these regulations shall mean the Division of Water Supply, Tennessee Department of Environment and Conservation, or one of the Division's Field Offices. The terms "State," "Department," and "Division" are often used interchangeably in these Rules and Regulations.

(22) "Diatomaceous earth filtration" means a process resulting in substantial particulate removal in which (1) a precoat cake of diatomaceous earth filter media is deposited on a support membrane (septum), and (2) while the water is filtered by passing through the cake on the

(Rule 1200-05-01-.04, continued)

septum, additional filter media known as body feed is continuously added to the feed water to maintain the permeability of the filter cake.

(23) "Direct filtration" means a series of processes including coagulation and filtration but excluding sedimentation resulting in substantial particulate removal.

(24) "Disinfectant" means any oxidant, including but not limited to chlorine, chlorine dioxide, chloramines, and ozone added to water in any part of the treatment or distribution process, that is intended to kill or inactivate pathogenic microorganisms.

(25) "Disinfectant contact time" ("T" in CT calculations) means the time in minutes that it takes for water to move from the point of disinfectant application or the previous point of disinfectant residual measurement to a point before or at the point where residual disinfectant concentration ("C") is measured. Where only one "C" is measured, "T" is the time in minutes that it takes for water to move from the point of disinfectant application to a point before or at where residual disinfectant concentration ("C") is measured. Where more than one "C" is measured, "T" is (a) for the first measurement of "C", the time in minutes that it takes for water to move from the first or only point of disinfectant application to a point before or at the point where the first "C" is measured and (b) for subsequent measurements of "C", the time in minutes that it takes for water to move from the previous "C" measurement point to the "C" measurement point for which the particular "T" is being calculated. Disinfectant contact time in pipelines must be calculated based on "plug flow" by dividing the internal volume of the pipe by the maximum hourly flow rate through that pipe. Disinfectant contact time within mixing basins and storage reservoirs must be determined by tracer studies or an equivalent demonstration.

(26) "Disinfection" means a process which inactivates pathogenic organisms in water by chemical oxidants or equivalent agents.

(27) “Disinfection profile” is a summary of daily Giardia lamblia inactivation through the treatment plant. The procedure for developing a disinfection profile is contained in 40CFR141.172.

(28) "Distribution System" means all water lines up to the point of a meter. For unmetered systems distribution system includes all lines up to the customer's service tap.

(29) "Domestic or other non-distribution system plumbing problem" means a coliform contamination problem in a public water system with more than one service connection that is limited to the specific service connection from which the coliform-positive sample was taken.

(30) "Dose Equivalent" means the product of the absorbed dose from ionizing radiation and such factors as account for differences in biological effectiveness due to the type of radiation and its distribution in the body as specified by the International Commission on Radiological Units and Measurements (ICRU).

(31) “Dual sample set” is a set of two samples collected at the same time and same location, with one sample analyzed for TTHM and the other sample analyzed for HAA5. Dual sample sets are collected for the purposes of conducting an IDSE under the provisions of 1200-05-01-.37 and determining compliance with the TTHM and HAA5 MCLs under the provisions of 1200-05-01-.38.

(32) "Effective corrosion inhibitor residual" for the purpose of the lead and copper rules only, means a concentration sufficient to form a passivating film on the interior walls of a pipe.

(33) "Engineer" means the person or firm who designed the public water system and conceived, developed, executed or supervised the preparation of the plan documents.

(Rule 1200-05-01-.04, continued)

(34) “Enhanced coagulation” means the addition of sufficient coagulant for improved removal of disinfection byproduct precursors by conventional filtration treatment

(35) “Enhanced softening” means the improved removal of disinfection byproduct precursors by precipitative softening.

(36) “Filter profile” is a graphical representation of individual filter performance, based on continuous turbidity measurements or total particle counts versus time for an entire filter run, from startup to backwash inclusively, that includes an assessment of filter performance while another filter is being backwashed.

(37) "Filtration" means a process for removing particulate matter from water by passage through porous media.

(38) “Finished water” is water that is introduced into the distribution system of a public water system and is intended for distribution and consumption without further treatment, except as treatment necessary to maintain water quality in the distribution system (e.g., booster disinfection, addition of corrosion control chemicals).

(39) "First draw sample" means a one-liter sample of tap water, for the purposes of the lead and copper rules, that has been standing in plumbing pipes at least 6 hours and is collected without flushing the tap.

(40) “Flocculation" means a process to enhance agglomeration or collection of smaller floc particles into larger, more easily settleable particles through gentle stirring by hydraulic or mechanical means.

(41) “Flowing stream” is a course of running water flowing in a definite channel.

(42) “GAC10” means granular activated carbon filter beds with an empty-bed contact time of 10 minutes based on average daily flow and a carbon reactivation frequency of every 180 days, except that the reactivation frequency for GAC10 used as best available technology for compliance with disinfection byproducts shall be 120 days.

(43) “GAC20” means granular activated carbon filter beds with an empty-bed contact time of 20 minutes based on average daily flow and a carbon reactivation frequency of every 240 days.

(44) "Gross Alpha Particle Activity" means the total radioactivity due to alpha particle emission as inferred from measurements on a dry sample.

(45) "Gross Beta Particle Activity" means the total radioactivity due to beta particle emission as inferred from measurements on a dry sample.

(46) “Ground water under the direct influence of surface water” means any water beneath the surface of the ground with significant occurrence of insects or other macroorganisms, algae, or large-diameter pathogens such as Giardia lamblia or Cryptosporidium, or significant and relatively rapid shifts in water characteristics such as turbidity, temperature, conductivity, or pH which closely correlate to climatological or surface water conditions. Direct influence must be determined for individual sources in accordance with criteria established by the State. The State determination of direct influence may be based on site-specific measurements of water quality and/or documentation of well construction characteristics and geology with field evaluation.

(Rule 1200-05-01-.04, continued)

(47) “Haloacetic acids (five) (HAA5)” mean the sum of the concentrations in milligrams per liter of the haloacetic acid compounds (monochloroacetic acid, dichloroacetic acid, trichloroacetic acid, monobromoacetic acid, and dibromoacetic acid), rounded to two significant figures after addition.

(48) "Halogen" means one of the chemical elements chlorine, bromine or iodine.

(49) “Human Consumption” - means the use of water that involves any drinking or ingestion of the water by humans, any human skin contact or food preparation where the food is not brought to boiling temperatures after contact with the water..

(50) "Initial compliance period" means the first full three-year compliance period which begins January 1, 1993. For public water systems having fewer than 150 service connections initial compliance period shall be January 2, 1996, for the following contaminants:

(a)	Antimony	(m)	endrin
(b)	Beryllium	(n)	glyphosate
(c)	Cyanide	(o)	oxamyl
(d)	Nickel	(p)	picloram
(e)	Thallium	(q)	simazine
(f)	dichloromethane	(r)	benzo(a)pyrene
(g)	1,2,4-trichlorobenzene	(s)	di(2ethylhexyl)adipate
(h)	1,1,2-trichloroethane	(t)	di(2ethylhexyl)phthalate
(i)	dalapon	(u)	hexachlorobenzene
(j)	dinoseb	(v)	hexachlorocyclopentadiene
(k)	diquat	(w)	2,3,7,8 TCDD
(l)	endothall		

(51) “Lake/reservoir” refers to a natural or man made basin or hollow on the earth’s surface in which water collects or is stored that may or may not have a current or single direction of flow.

(52) "Large water system" for the purpose of lead and copper rule, means a water system that serves more than 50,000 persons.

(53) "Lead service line" means a service line made of lead which connects the water main to the building inlet and any lead pigtail, gooseneck or other fitting which is connected to such lead line.

(54) "Legionella" means a genus of bacteria, some species of which have caused a type of pneumonia called Legionnaires Disease.

(55) “Locational running annual average (LRAA)” is the average of sample analytical results for samples taken at a particular monitoring location during the previous four calendar quarters.

(56) "Man-Made Beta Particle and Photon Emitter" means all radionuclides emitting beta particles and/or photons listed in "Maximum Permissible Body Burdens and Maximum Permissible Concentration of Radionuclides in Air or Water for Occupational Exposure, NBS Handbook 69", except the daughter products of thorium-232, uranium-235 and uranium-238.

(57) "Maximum Contaminant Level" means the maximum permissible level of a contaminant in water which is delivered at the free flowing outlet of the ultimate user of a public water system, except in the case of turbidity where the maximum permissible level is measured at the point of entry to the distribution system. Contaminants added to the water under

(Rule 1200-05-01-.04, continued)

circumstances controlled by the user, except those resulting from corrosion of piping and plumbing caused by water quality, are excluded from this definition.

(58) “Maximum residual disinfectant level (MRDL)” means a level of a disinfectant added for water treatment that may not be exceeded at the consumer’s tap without an unacceptable possibility of adverse health effects. For chlorine and chloramines, a PWS is in compliance with the MRDL when the running annual average of monthly averages of samples taken in the distribution system, computed quarterly, is less than or equal to the MRDL. For chlorine dioxide, a PWS is in compliance with the MRDL when daily samples are taken at the entrance to the distribution system and no two consecutive daily samples exceed the MRDL. MRDLs are enforceable in the same manner as maximum contaminant levels under Section 1412 of the Safe Drinking Water Act. There is convincing evidence that addition of a disinfectant is necessary for control of waterborne microbial contaminants. Notwithstanding the MRDLs, operators may increase residual disinfectant levels of chlorine or chloramines (but not chlorine dioxide) in the distribution system to a level and for a time necessary to protect public health to address specific microbiological contamination problems caused by circumstances such as distribution line breaks, storm runoff events, source water contamination, or cross-connections.

(59) "Maximum Total Trihalomethane Potential (MTP)" means the maximum concentration of total trihalomethanes produced in a given water containing a disinfectant residual after 7 days at a temperature of 25°C or above.

(60) "Medium-size water system" for the purpose of the lead and copper rule means a water system that serves greater than 3,300 and less than or equal to 50,000 persons.

(61) “Membrane filtration” is a pressure or vacuum driven separation process in which particulate matter larger than 1 micrometer is rejected by an engineered barrier, primarily through a size exclusion mechanism, and which has a measurable removal efficiency of a target organism that can be verified through the application of a direct integrity test. This definition includes the common membrane technologies of microfiltration, ultrafiltration, nanofiltration, and reverse osmosis.

(62) "Near the first service connection" means at one of the twenty percent of all service connections in the entire system that are nearest the water supply treatment facility, as measured by the water transport time within the distribution system.

(63) "Non-Community Water System" means a public water system that is not a community water system.

(64) "Non-Transient Non-Community Water System" or NTNCWS" means a non-community water system that regularly serves at least twenty-five (25) of the same persons over six (6) months per year.

(65) "Optimal corrosion control treatment" for the purpose of lead and copper rule only means the corrosion control treatment that minimizes the lead and copper concentrations at user's taps while insuring that the treatment does not cause the water system to violate any primary drinking water regulation.

(66) "Person" means any individual, corporation, company, association, partnership, State, municipality, utility district, water cooperative, or Federal agency.

(67) "Picocurie" (pCi) means that quantity of radioactive material producing 2.22 nuclear transformations per minute.

(Rule 1200-05-01-.04, continued)

(68) "Plan Documents" mean reports, proposals, preliminary plans, survey and basis of design data, general and detailed construction plans, profiles, specifications and all other information pertaining to public water system planning.

(69) “Plant intake” refers to the works or structures at the head of a conduit through which water is diverted from a source (e.g., river or lake) into the treatment plant.

(70) "Point of disinfectant application" is the point where the disinfectant is applied and water downstream of that point is not subject to recontamination by surface water runoff.

(71) "Point-of-Entry Treatment Device" (POE) means a device applied to the drinking water entering a house or building for the purpose of reducing contaminants in the drinking water distributed throughout the house or building.

(72) "Point-of-Use Treatment Device" (POU) means a treatment device applied to a single tap used for the purpose of reducing contaminants in drinking water at that one tap.

(73) ‘Presedimentation” is a preliminary treatment process used to remove gravel, sand and other particulate material from the source water through settling before the water enters the primary clarification and filtration processes in a treatment plant.

(74) "Primary Drinking Water Regulation" means a regulation promulgated by the Department which:

(a) applies to public water systems;

(b) specifies contaminants which, in the judgment of the Department, may have any adverse effect on the health of persons;

(c) specified for each such contaminant either;

1. a <u>maximum contaminant level</u>, if, in the judgment of the Department, it is economically and technologically feasible to ascertain the level of such contaminant in water in public water systems, or

2. if, in the judgment of the Department, it is not economically or technologically feasible to so ascertain the level of such contaminant, each <u>treatment technique</u> known to the Department which leads to a reduction in the level of such contaminant sufficient to satisfy the requirements of Regulations 1200-05-01-.06; and

(d) contains criteria and procedures to assure a supply of drinking water which dependably complies with such maximum contaminant levels; or treatment techniques including quality control and testing procedures to insure compliance with such levels and to insure proper operation and maintenance of the system, and requirements to (i) the minimum quality of water which may be taken into the system and (ii) siting for new facilities for public water systems.

(75) “Public Water System” means a system for the provision of piped water for human consumption if such serves 15 or more connections or which regularly serves 25 or more individuals daily at least 60 days out of the year and includes:

(a) any collection, treatment, storage or distribution facility under control of the operator of such system and used primarily in connection with such system; and

(Rule 1200-05-01-.04, continued)

(b) any collection or pre-treatment storage facility not under such control which is used primarily in connection with such system,

The population of a water system shall be determined by actual count or by multiplying the household factor by the number of connections in the system. The household factor shall be taken from the latest federal census for that county or city. Water systems serving multi-family residences such as apartment complexes and mobile home parks shall include each individual residence unit as a connection in determining the population for the system.

(76) "Rem" means the unit of dose equivalent from ionizing radiation to the total body or any internal organ or organ system. A "millerem (mrem)" is 1/1000 of a rem.

(77) "Repeat compliance period" means any subsequent compliance period after the initial compliance period.

(78) "Residual disinfectant concentration" ("C" in CT calculations) means the concentration of disinfectant measured in mg/l in a representative sample of water.

(79) "Safe Drinking Water Act" means the Federal law codified in 42 United States Code 300f et. seq., Public Law 93-523, dated December 16, 1974 and subsequent amendments..

(80) "Sanitary Survey" means an on-site review of the water source, facilities, equipment, operation and maintenance of a public water system for the purpose of evaluating the adequacy of such sources, facilities, equipment, operation and maintenance for producing and distributing safe drinking water.

(81) "Secondary Drinking Water Regulation" mean a regulation promulgated by the Department which applies to public water systems and which specifies the maximum contaminant levels which, in the judgment of the Department 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 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 according to geographic and other circumstances.

(82) "Sedimentation" means a process for removal of solids before filtration by gravity or separation.

(83) "Service line sample" means a one-liter sample of water collected in accordance with 1200-05-01-.33(7)(b)3., that has been standing for at least 6 hours in a service line.

(84) "Single family structure" for the purpose of lead and copper rules means a building constructed as a single-family residence that is currently used as either a residence or a place of business.

(85) "Slow sand filtration" means a process involving passage of a raw water through a bed of sand at low velocity (generally less than 0.4 m/h) resulting in substantial particulate removal by physical and biological mechanisms.

(86) "Small water system" for the purpose of the lead and copper rules only, means a water system that serves 3,300 or fewer persons.

(Rule 1200-05-01-.04, continued)

(87) “Subpart H systems” means public water systems using surface water or ground water under the direct influence of surface water as a source that are subject to the requirements 1200-05-01-.31, .39 and 1200-05-01-.17.

(88) "Supplier of Water" means any person who owns or operates a public water system.

(89) "Surface water" means all water which is open to the atmosphere and subject to surface runoff.

(90) “SUVA” means Specific Ultraviolet Absorption at 254 nanometers (nm), an indicator of the humic content of water. It is a calculated parameter obtained by dividing a sample’s ultraviolet absorption at a wavelength of 254 nm (UV 254/ (in m) by its concentration of dissolved organic carbon (DOC) (in mg/L).

(91) "System with a single service connection" means a system which supplies drinking water to consumers via a single service line.

(92) "Too numerous to count" means that the total number of bacterial colonies exceeds 200 on a 47 millimeter diameter membrane filter used for coliform detection.

(93) “Total Organic Carbon (TOC)” means total organic carbon in mg/L measured using heat, oxygen, ultraviolet irradiation, chemical oxidants, or combinations of these oxidants that convert organic carbon to carbon dioxide, rounded to two significant figures.

(94) "Total trihalomethane" (TTHM) means the sum of concentration in milligrams per liter of the trihalomethane compounds-trihalomethane (chloroform), dibromochloromethane, bromodichloro-methane and tribomomethane (bromoform), rounded to two significant figures.

(95) “Transient Non-Community Water System” or “TNCWS” means a non-community water system that regularly serves at least twenty-five (25) individuals daily at least sixty (60) days out of the year. A transient non-community water system is a public water supply system that generally serves a transient population such as hotels, motels, restaurants, camps, service stations churches, industry, and rest stops.

(96) "Trihalomethane" (THM) means one of the family of organic compounds, named as derivatives of methane, wherein three of the four hydrogen atoms in methane are each substituted by a halogen atom in the molecular structure.

(97) “Two-stage lime softening” is a process in which chemical addition and hardness precipitation occur in each of two distinct unit clarification processes.

(98) “Uncovered finished water storage facility” is a tank, reservoir, or other facility used to store water that will undergo no further treatment except residual disinfection and is open to the atmosphere.

(99) “Viable Water System” means a public water system which has the commitment and the financial, managerial and technical capacity to consistently comply with the Tennessee Safe Drinking Water Act and these regulations.

(100) "Virus" means a virus of fecal origin which is infectious to humans by waterborne transmission.

(101) “Waterborne disease outbreak" means a significant occurrence of acute infectious illness, epidemiologically associated with the ingestion of water from a public water system which is deficient in treatment, as determined by the appropriate local or State agency.

(Rule 1200-05-01-.05, continued)

plan documents it has approved to the Division of Water Supply. This shall be done within 10 days of the local government's approval. The commissioner may periodically review the unit of local government's plans review program and prescribe changes as deemed appropriate. The Division of Water Supply may execute a written agreement with a unit of local government which has received plans review certification. Failure to comply with the terms of the agreement may result in revocation of the plans review certification.

Authority: *T.C.A. §§4-5-201 et seq., 4-5-202, 68-221-701 et seq., and 68-221-704.* ***Administrative History:*** *Original rule certified June 7, 1974. Repeal and new rule filed June 30, 1977; effective August 1, 1977. Amendment filed February 3, 1984; effective February 12, 1985. Amendment filed August 24, 1992; effective October 8, 1992. Amendment filed April 12, 1996; effective June 26, 1996. Amendment filed October 31, 2000; effective January 14, 2001. Amendments filed August 15, 2005; effective October 29, 2005.*

1200-05-01-.06 MAXIMUM CONTAMINANT LEVELS.

(1) Inorganic Chemicals

(a) The maximum contaminant level for fluoride applies to community water systems. The maximum contaminant levels for nitrate, nitrite and total nitrate and nitrite are applicable to both community water systems and non-community water systems. The maximum contaminant levels for the remaining inorganic chemicals apply only to community water systems and non-transient non-community systems. The effective date for antimony, beryllium, cyanide, nickel and thallium shall be January 1, 1993, or the effective date of this rule whichever is later. The arsenic maximum contaminant level listed in subparagraph (b)2 is effective for the purpose of compliance January 23, 2006. Until January 23, 2006, the arsenic MCL is 0.05 mg/L.

(b) The following are the maximum contaminant levels for inorganic chemicals:

CONTAMINANT		LEVEL, MILLIGRAMS PER LITER
1.	Antimony	0.006
2.	Arsenic	0.010
3.	Asbestos	7 million fibers/liter (longer than 10 microns)
4.	Beryllium	0.004
5.	Barium	2.0
6.	Cadmium	0.005
7.	Chromium	0.1
8.	Cyanide (as free cyanide)	0.2
9.	Fluoride	4.0
10.	Mercury	0.002
11.	Nickel	0.1
12.	Nitrate	10.0 (as Nitrogen)
13.	Nitrite	1.0 (as Nitrogen)
14.	Total nitrate and nitrate	10.0 (as Nitrogen)
15.	Selenium	0.05
16.	Thallium	0.002

(2) Organic Chemicals - The following are the maximum contaminant levels for organic chemicals.

(a) The following maximum contaminant levels for organic contaminants apply to community water systems and non-transient non-community water systems. The effective date of these MCLs shall be the effective date of this regulation.

(Rule 1200-05-01-.06, continued)

	CONTAMINANT	LEVEL, MILLIGRAMS PER LITER
1.	Alachlor	0.002
2.	Atrazine	0.003
3.	Carbofuran	0.04
4.	Chlordane	0.002
5.	Dibromo chloropropane (DBCP)	0.0002
6.	2,4 Dichlorophenoxyacetic acid	0.07
7.	Ethylene dibromide	0.00005
8.	Heptachlor	0.0004
9.	Heptachlor epoxide	0.0002
10.	Lindane	0.0002
11.	Methoxychlor	0.04
12.	Polychlorinated biphenyls	0.0005
13.	Toxaphene	0.003
14.	2,4,5 Trichlorophenoxyproprionic acid	0.05
15.	Pentachlorophenol	0.001
16.	Benzo(a)pyrene	0.0002
17.	Dalapon	0.2
18.	Di(2-ethylhexyl) adipate	0.4
19.	Di(2-ethylhexyl)phthalate	0.006
20.	Dinoseb	0.007
21.	Diquat	0.02
22.	Endothall	0.1
23.	Glyphosate	0.7
24.	Hexachlorobenzene	0.001
25.	Hexachlorocyclopentadiene	0.05
26.	Oxamyl (Vydate)	0.2
27.	Picloram	0.5
28.	Simazine	0.004
29.	2,3,7,8-TCDD (Dioxin)	0.00000003
30.	Endrin	0.002

(3) Turbidity - The requirements of 1200-05-01-.06(3) apply to filtered surface systems until June 29, 1993. The requirements in this section apply to unfiltered systems that the State has determined, in writing, must install filtration until June 29, 1993, or until filtration is installed, whichever is later.

The maximum contaminant level for turbidity is applicable to public water systems using surface water source(s) in whole or in part. Furthermore, the maximum contaminant level for turbidity is applicable to those systems using ground water which are required to install turbidimeters pursuant to Regulation 1200-05-01-.05(11). The maximum contaminant levels for turbidity in drinking water, measured at a representative entry point(s) to the distribution system are:

(a) One (1.0) turbidity unit, as determined by monthly average pursuant to Regulation 1200-05-01-.08.

(b) Two (2.0) turbidity units based on an average for two consecutive days pursuant to Regulation 1200-05-01-.08.

To meet the maximum contaminant level for turbidity, a public water system must meet both (a) and (b).

(Rule 1200-05-01-.06, continued)

(4) Microbiological - The maximum contaminant levels for microbiologicals are applicable to both community water systems and non-community water systems.

(a) The maximum contaminant level (MCL) is based on the presence or absence of total coliforms in a sample, rather than coliform density.

The number of total coliform positive samples shall not exceed any of the following:

1. For a system which collects at least 40 samples per month, if no more than 5.0 percent of the samples collected during a month are total coliform-positive, the system is in compliance with the MCL for total coliforms.

2. For a system which collects fewer than 40 samples/month, if no more than one sample collected during a month is total coliform-positive, the system is in compliance with the MCL for total coliforms.

3. A public water system which has exceeded the MCL for total coliforms must report the violation to the State no later than the end of the next business day after it learns of the violation and notify the public in accordance with the schedule of 1200-05-01-.19 using the language specified in 1200-05-01-.19.

4. A public water system which has failed to comply with the coliform monitoring requirements, including a sanitary survey requirement must report the monitoring violation to the State within ten (10) days after the system discovers the violation and notify the public in accordance with 1200-05-01-.19.

(b) Any fecal coliform-positive repeat sample or E-coli-positive repeat sample, or any total coliform-positive repeat sample following a fecal coliform positive or E-coli positive routine sample constitutes a violation of the MCL for total coliforms. For purposes of the public notification requirements in 1200-05-01-.19 this is a tier 1 violation that may pose an acute risk to health.

(c) Fecal coliforms/Escherichia coli (E. coli) testing

1. If any routine or repeat sample is total coliform-positive, the system must analyze that total coliform-positive culture medium to determine if fecal coliforms are present, except that the system may test for E. coli in lieu of fecal coliforms. If fecal coliforms or E. coli are present, the system must notify the State by the end of the day when the system is notified of the test result, unless the system is notified of the result after the Department office is closed, in which case the system must notify the State before the end of the next business day.

2. The State has the discretion to allow a public water system, on a case-by-case basis, to forgo fecal coliform or E. coli testing on a total coliform-positive sample if that system assumes that the total coliform-positive sample is fecal coliform-positive or E. coli-positive. Accordingly, the system must notify the State as specified in paragraph (c)(1) of this section and the provisions of 1200-05-01-.06(4)(b) apply.

(d) A public water system must determine compliance with the MCL for total coliforms in (a) and (b) of this section for each month in which it is required to monitor for total coliforms.

(e) No variance or exemptions from the maximum contaminant level for total coliforms are permitted.

(Rule 1200-05-01-.06, continued)

1. The following are identified as the best technology, treatment technology or other means available for achieving compliance with the maximum residual disinfectant level:

   (i) Control of the treatment processes to reduce disinfectant demand and control of disinfection treatment processes to reduce disinfectant levels.

Authority: T.C.A. §68-221-704. ***Administrative History:*** *Original rule certified June 7, 1974. Repeal and new rule filed June 30, 1977; effective August 1, 1977. Amendment filed February 3, 1984; effective February 12, 1985. Amendment filed September 26, 1988; effective November 10, 1988. Amendment filed November 26, 1990; effective January 10, 1991. Amendment filed August 24, 1992; effective October 8, 1992. Amendment filed October 22, 1993; effective January 5, 1994. Amendment filed October 31, 2000; effective January 14, 2001. Amendment filed November 21, 2001; effective February 4, 2002. Amendment filed April 12, 2002; effective June 26, 2002. Amendment filed July 15, 2002; effective September 28, 2002. Amendment filed April 19, 2004; effective July 3, 2004. Amendment filed July 31, 2006; effective October 14, 2006.*

1200-05-01-.07 MONITORING AND ANALYTICAL REQUIREMENTS.

(1) Microbiological Contaminant Sampling

(a) Reserved

(b) Reserved

(c) The supplier of water for a community water system shall take coliform samples at regular time intervals and in number proportional to the population served by the system during the reporting period as set forth below:

TOTAL COLIFORM MONITORING FREQUENCY FOR COMMUNITY WATER SYSTEMS

Population Served	Minimum Number of Samples Per Month
25 to 1,000[1]	1
1,001 to 2,500	2
2,501 to 3,300	3
3,301 to 4,100	4
4,101 to 4,900	5
4,901 to 5,800	6

Population Served	Minimum Number of Samples Per Month
5,801 to 6,700	7
6,701 to 7,600	8
7,601 to 8,500	9
8,501 to 12,900	10
12,901 to 17,200	15
17,201 to 21,500	20
21,501 to 25,000	25
25,001 to 33,000	30
33,001 to 41,000	40
41,001 to 50,000	50

(Rule 1200-05-01-.07, continued)

50,001 to 59,000	60
59,001 to 70,000	70
70,001 to 83,000	80
83,001 to 96,000	90
96,001 to 130,000	100
130,001 to 220,000	120
220,001 to 320,000	150
320,001 to 450,000	180
450,001 to 600,000	210
600,001 to 780,000	240
780,001 to 970,000	270
970,001 to 1,230,000	300
1,230,001 to 1,520,000	330
1,520,001 to 1,850,000	360
1,850,001 to 2,270,000	390
2,270,001 to 3,020,000	420
3,020,001 to 3,960,000	450
3,960,001 or more	480

[1] Includes public water systems which have at least 15 service connections, but serve fewer than 25 persons.

1. Coliform samples shall be collected at sites which are representative of water throughout the distribution system according to a written sample siting plan.

2. Sample siting plans shall be made available to the Department on request. Plans determined to be deficient by the Department shall be revised by the system on the basis of the Department's findings.

3. Microbiological sampling shall be conducted in accordance with the approved sampling plan.

(d) The monitoring frequency for total coliforms for non-community water systems is as follows:

1. A non-community water system using only ground water (except ground water under the direct influence of surface water) and serving 1,000 persons or fewer must monitor each calendar quarter that the system provides water to the public.

2. A non-community water system using only ground water (except ground water under the direct influence of surface water) and serving more than 1,000 persons during any month must monitor at the same frequency as a like-sized community water system, as specified in Rule 1200-05-01-.07(1)(c). For systems using ground water under the direct influence of surface water, rule 1200-05-01-.07(1)(d)4. applies.

3. A non-community water system using surface water, in total or in part, must monitor at the same frequency as a like-sized community water system, as specified in 1200-05-01-.07(1)(c), regardless of the number of persons it serves.

4. A non-community water system using ground water under the direct influence of surface water must monitor at the same frequency as a like-sized community water system, as specified in 1200-05-01-.07(1)(c). The system must begin monitoring at this frequency beginning six months after the determination that the ground water is under the direct influence of surface water.

(Rule 1200-05-01-.11, continued)

5. If the MCL for radioactivity set forth in Rule 1200-05-01-.06(5) is exceeded, the operator of a community water system must give notice to the Department pursuant to Rule 1200-05-01-.20 and to the public as required by Rule 1200-05-01-.19.

Authority: *T.C.A. §§4-5-201 et seq., 4-5-202, 53-2002, 53-2003; 68-221-701 et seq., 68-221-704, and Public Acts of 1983, Chapter 324.* ***Administrative History:*** *Original rule filed June 30, 1977; effective August 1, 1977. Amendment filed February 3, 1984; effective February 12, 1985. Amendment filed August 24, 1992; effective October 8, 1992. Amendment filed November 21, 2001; effective February 4, 2002. Amendment filed April 12, 2002; effective June 26, 2002. Amendment filed August 15, 2005; effective October 29, 2005. Amendments filed June 12, 2008; effective August 26, 2008.*

1200-05-01-.12 SECONDARY DRINKING WATER REGULATIONS.

(1) The following maximum contaminant levels are established to provide a water that is aesthetically pleasing to the consumer. These standards will apply to all community water systems and to those non-community water systems as may be deemed necessary by the Department. Monitoring for these contaminants will be set in the Monitoring Program for each system, but in no event less than once every year for a surface and surface/ground supply and once every three years for a ground water supply.

Maximum Contaminant Level

Contaminant	Milligrams per Liter (unless otherwise indicated)
(a) Chloride	250
(b) Color	15 (Color Units)
(c) Copper	1
(d) MBAS (Methyl Blue Active Substance)	0.5
(e) Iron	0.3
(f) Manganese	0.05
(g) Odor	3 (Threshold Odor Number)
(h) pH	6.5-8.5
(i) Sulfate	250
(j) TDS (Total Dissolved Solids)	500
(k) Zinc	5
(l) Fluoride	2.0
(m) Aluminum	0.2
(n) Silver	0.1

(2) The system may apply for monitoring waivers from the monitoring frequency specified in paragraph (1). The Department may issue monitoring waivers after considering: historical data, whether or not there have been customer complaints concerning the contaminant to be waived, any corrective action taken by the water supplier to correct the secondary contaminant problem, and whether or not the system routinely monitors for the contaminant as part of its treatment process monitoring program. The Department shall determine the frequency, if any, a system must monitor after considering the historical data available, the number and nature of customer complaints and other factors that may affect the contaminant concentration, and specify the decision in writing to the system.

Authority: *T.C.A. §§4-5-201 et seq., 4-5-202, 68-221-701 et seq, and 68-221-704.* ***Administrative History:*** *Original rule filed June 30, 1977; effective August 1, 1977. Amendment filed February 3, 1984; effective February 12, 1985. Amendment filed September 26, 1988; effective November 10, 1988. Amendment filed August 24, 1992; effective October 8, 1992. Amendment filed April 12, 1996; effective*

(Rule 1200-05-01-.16, continued)

(b) Except for intake structures, is within the flood plain of a 100-years flood.

(2) All other siting requirements shall be in accordance with those set forth in "Design Criteria for Public Water Systems" as published by the Department.

Authority: *T.C.A. §§4-5-201 et seq. and 68-221-701 et seq.* ***Administrative History:*** *Original rule filed June 30, 1977; effective August 1, 1977. Amendment filed April 12, 1996; effective June 26, 1996.*

1200-05-01-.17 OPERATION AND MAINTENANCE REQUIREMENTS.

(1) All community water systems which are designated as a surface supply and classified as a filtration system and all iron removal plants which use gravity filters must have an operator in attendance and responsible for the treatment process when the plant is in operation. Gravity iron removal plants which have installed continuous monitoring equipment including equipment for turbidity and chlorine residual with alarms and/or shutdown ability may seek approval from the Department to operate the treatment plant in an automated mode without an operator in attendance. All iron removal plants with pressure filters and using a ground water source from an approved sand and gravel formation will not be required to have an operator in attendance during all periods of operation provided suitable protection, acceptable to the Department, is provided.

Non–community water systems which are classified as a surface supply will be required to have a full time operator in attendance unless certain continuous monitoring equipment is installed.

Pursuant to Tennessee Code Annotated 68–221–904, all operators in direct responsible charge of a water supply system, including the treatment plant and/or distribution system, must be certified by the Department as competent to operate same.

Because the proper operation and maintenance of water systems is critical to a system's ability to provide safe water to the public and to comply with these rules, all water supply systems must comply with the provisions of Rule 1200-05-03. A violation of those rules is a violation of this rule as well.

(2) All community water systems and those non-community water systems classified as a surface source shall compile and maintain accurate daily operating records of the water works system on forms prepared and furnished by the Department. The daily operating records shall be submitted in a timely manner so they are received by the Department no later than <u>ten days</u> after the end of the reporting month. Any special reports, deemed necessary by the Department to assure continuous satisfactory operation of the water system, shall be submitted to the Department.

Water systems which desire to use their own forms to report the daily operating results to the Department must have prior approval of the form from the Department.

(3) All water quality tests, other than those listed in Regulation 1200-05-01-.06 shall be made in accordance with the latest edition of "Standard Methods for the Examination of Water and Wastewater" or alternate methods acceptable to the Department. The schedule of laboratory tests followed in controlling the operation of a waterworks system will vary with the character of the water; therefore, all waterworks systems must have the equipment necessary to perform all laboratory tests pertinent to the control of the plant or system operation, and the equipment shall be maintained in good working order at all times. Laboratory tests pertinent to proper operation shall be prescribed by the Department for each community water system.

(4) Chlorine is the recommended disinfection agent. Other agents will be considered by the Department provided they are effective and testing procedures for their effectiveness are

(Rule 1200-05-01-.17, continued)

recognized in the latest edition of "Standard Methods for the Examination of Water and Wastewater". All community water systems, using ground water as a raw water source and serving more than 50 connections or 150 persons shall continuously chlorinate (unless other disinfection methods are approved) and shall maintain a free chlorine residual in all parts of the distribution system in the amount of not less than 0.2 mg/l. Public Water Systems using surface water shall continuously chlorinate and maintain a free chlorine residual of 0.2 mg/l in all parts of the distribution system. The residual disinfectant concentration specified by this rule shall not be less than 0.2 mg/l in more than 5 percent of the samples each month, for any two consecutive months the system serves water to the public. All public water systems serving 50 or fewer connections that do not disinfect shall install continuous disinfection if the system fails to comply with the maximum contaminant level for coliform, experiences a disease outbreak or is directed to install disinfection by the department. All public water systems serving 50 or fewer connections that do not disinfect shall install continuous disinfection if the system fails to comply with the maximum contaminant level for coliform, experiences a disease outbreak or is directed to install disinfection by the department.

(5) All systems submitting samples for microbiological examination to the State laboratory must submit said sample in the bottle(s) provided by the State and return the samples to the proper State laboratory in the shipping carton provided by the State. The cost of postage for shipping the sample to the proper State laboratory shall be paid by the supplier of water. All samples submitted for microbiological examination must be collected and mailed to arrive at the proper State laboratory not later than Thursday noon of any week. Thirty hours is the limit allowed from the time of collection to the time of examination at the proper State laboratory.

(6) Pursuant to Section 68–221–711(6) the installation, allowing the installation, or maintenance of any cross–connection, auxiliary intake, or bypass is prohibited unless the source and quality of water from the auxiliary supply, the method of connection, and the use and operation of such cross–connection, auxiliary intake, or bypass has been approved by the Department. The arrangement of sewer, soil, or other drain lines or conduits carrying sewage or other wastes in such a manner that the sewage or waste may find its way into any part of the public water system is prohibited.

All community water systems must adopt an ordinance or policy prohibiting all of the above and submit a copy of the executed ordinance or policy to the Department for approval. All community water systems shall develop a written plan for a cross–connection control program to detect and eliminate or protect the system from cross–connections. The written plan must be approved by the Department.

After adoption and approval of the cross–connection ordinance or policy and plan, each community water system must establish an ongoing program for the detection and elimination of hazards associated with cross–connections. Records of the cross–connection control program must be maintained by the water supplier and shall include such items as date of inspection, person contacted, recommendations, follow–up, and testing results.

(a) Public water systems must develop and implement an ongoing cross-connection program. Cross-connection plans and policies shall present all information in conformance with the "Design Criteria for Community Public Water Systems" as published by the Department.

(b) The public water system shall ensure that cross-connections between the distribution system and a consumer's plumbing are surveyed and/or inspected and determined not to exist or contain a significant risk or are eliminated or controlled by the installation of an approved backflow preventer commensurate with the degree of hazard.

(7) Within one year after the effective date of these regulations all community water system shall prepare an emergency operations plan in order to safeguard the water supply and to alert the

(Rule 1200-05-01-.17, continued)

public of unsafe drinking water in the event of natural or man-made disasters. Emergency operation plans shall be consistent with guidelines established by the State and shall be reviewed and approved by the Department.

(8) (a) General-Public water systems, construction contractors and engineers shall follow and document sanitary practices used in inspecting, constructing or repairing water lines, finished water storage facilities, filters and wells. In lieu of writing their own disinfection standard operating procedures, public water systems, engineers and contractors may chose to follow the latest edition of the AWWA standards C-651, C-652 or equivalent methods provided the method has been approved in writing by the department and is available during the inspection, construction, maintenance or repair activity. The documentation shall include bacteriological sample results, construction logs, standard operating procedures and may include photographs where appropriate. All pipes, tanks, filters, filter media and other materials shall be properly disinfected prior to being placed in service. Any disinfectant used to disinfect shall be NSF approved or plain household bleach and used in a manner that assures sufficient contact time and concentration to inactivate any pathogens present. Bacteriological results including line repair records indicating adequacy of disinfection shall be maintained on file by the water system for five years. All public water systems, contractors, and engineers shall prepare and follow standard disinfection procedures approved by the state when inspecting, maintaining, repairing or constructing lines, tanks, filters and wells. Procedures to ensure that water containing excessive concentrations of disinfectant is not supplied to the customers or discharged in such manner as to harm the environment shall be implemented.

All materials used for new or repaired water lines, storage facilities, filters, filter media, and wells will be inspected prior to use for any evidence of gross contamination. Any contamination observed shall be removed and the materials protected during installation.

(b) Disinfection of New Facilities-Bacteriological samples will be collected and analyzed to verify the effectiveness of the disinfection practices prior to placing new facilities in service. Bacteriological samples shall be collected to determine the effectiveness of the installation process including protecting the pipe material during storage, installation, and disinfection. This can be demonstrated by collecting two sets of microbiological samples 24 hours apart or collecting a single set of microbiological samples 48 hours or longer after flushing the highly chlorinated water from the lines. In either case microbiological samples in each set will be collected at approximately 2,500-foot intervals with samples near the beginning point and at the end point unless alternate sampling frequency and distance between sampling points approval has been obtained from the state. Where sanitary conditions were not maintained before, during or after construction, an additional bacteriological sample shall be collected from a location representing the water from the contaminated area. Unsanitary conditions include failure to document the sanitary handling of materials, to conduct construction inspections and to maintain records, and to document sanitary practices during construction and other hazards such trench flooding during construction. If the constructed facility yields positive bacterial samples, additional flushing, disinfection and bacteriological sampling shall be repeated until the water is coliform free.

(c) Disinfection of Existing Facilities-Drinking water mains, storage facilities and filters that have been partially dewatered during inspection or repair shall, after the repair or inspection is completed, be disinfected, and flushed prior to placing it back in service. Bacteriological samples shall be collected immediately or as soon as possible after the repair is completed and from a location representing the water contained in the repaired line, tank or filter. The repaired facility may be returned to service prior to obtaining bacteriological results. If the repaired facility yields positive bacterial

(Rule 1200-05-01-.17, continued)

samples, additional flushing, disinfection and bacteriological sampling shall be repeated until the water is coliform free.

1. If one-half or more of either the original or repeat bacteriological samples collected from the repaired or renovated facility are total coliform positive, the system shall notify the state within 30 days that it has reviewed its disinfection and sampling practices in an attempt to identify why the positive samples occurred and revise its disinfection and sampling plans accordingly.

2. If any public water system collects a fecal coliform positive repeat sample or e-coli positive repeat sample or a total coliform positive repeat sample following an initial positive fecal coliform or e-coli sample collected from the repaired or renovated facility, the system shall notify the state within 24-hours and issue a tier 1 public notice using the language specified in Appendix B of Rule 1200-05-01-.19.

(d) Inspectors, contractors, operators, public water systems or engineers that fail to document and follow adequate disinfection procedures, and fail to collect bacteriological samples during repairs, inspections or maintenance activities that potentially would compromise the microbial quality of the water shall issue a boil water advisory to the customers served by that portion of the public water system prior to returning the facility to service. The boil water advisory shall remain in effect until satisfactory microbial tests results are obtained.

(9) All community water systems shall be operated and maintained to provide minimum positive pressure of twenty (20) psi throughout the distribution system. No person shall install or maintain a water service connection to any premises where a booster pump has been installed unless such booster pump is equipped with a low pressure cut-off mechanism designed to cut off the booster pump when the pressure on the suction side of the pump drops to twenty (20) psi gauge.

(10) All community water systems having more than 50 service connections shall establish and maintain an adequate flushing program. The flushing program established shall help ensure that dead end and low usage mains are flushed periodically, drinking water standards are met, sediment and air removal and the free chlorine residual specified under Rule 1200-05-01.17(4) is maintained. Records of each flushing are to be maintained by the water system. These records shall include date, time, location, persons responsible and length of flushing. In addition to the above information, the free chlorine residual will have to be measured and recorded on the end of dead end mains after being flushed.

(11) All community public water systems serving more than 50 connections and which have their own source of water shall be required to install, operate and maintain duplicate disinfection equipment. Duplicate disinfection equipment means at least two chlorine cylinders connected to at least two chlorinators. Each set of chlorine cylinders consists of one or more cylinders which may be connected together by an automatic switchover valve. The two sets of chlorine cylinders may tee in to a common feed line leading to the chlorinators, but may not be connected together by an automatic switchover valve. The two sets of chlorine cylinders must be weighed independently and operated simultaneously. At least two chlorinators must be operated at all times with each feeding a part of the required dosage. The chlorinators may discharge to a common manifold piping network to allow multiple injection points. Facilities may be exempt from simultaneously operating duplicate disinfection equipment if the facility has a reliable chlorine residual analyzer with an alarm notifying a manned control center capable of immediately shutting down the treatment facility. Facilities, which are staffed during the time water is treated, can use one set of chlorine cylinders with the automatic switchover device provided the free chlorine residual is checked at the facility every two hours. A reliable free chlorine residual analyzer with an alarm system

(Rule 1200-05-01-.17, continued)

to a manned control center may be used for unmanned facilities that desire to use one set of chlorine cylinders with the automatic switchover device.

Community public water systems serving more than 50 service connections which use a hypochlorinator shall be required to have two solution pumps, two tanks for bleach solution and operate both units at the same time. Noncommunity systems and community systems serving less than 50 connections which use a hypochlorinator and show deficiencies in the disinfection process shall also be required to have duplicate disinfection units.

(12) All public water systems which utilize a filtration system shall use the following bed specifications and not exceed the following rates of filtration.

(a) Rapid Sand Filtration - 2.0 gallons per minute per square foot for turbidity removal, 3.0 gallons per minute per square foot for iron removal.

There must be 30 inches of sand media with an effective size of 0.35 mm to 0.55 mm and a uniformity coefficient not greater than 1.70

(b) High Rate Filtration - 4.0 gallons per minute per square foot for turbidity removal, 4.0 gallons per minute per square foot for iron removal.

There must be 30 inches of dual media with 10 to 12 inches of sand and 18 to 20 inches of anthracite. The sand shall have an effective size of 0.35 mm to 0.55 mm and a uniformity coefficient not greater than 1.70. The anthracite shall have an effective size of 0.8 mm to 1.2 mm with a uniformity coefficient not greater than 1.85.

(c) Existing water systems with rapid sand filters and approved for higher rates of filtration by the Department will be allowed to continue at that rate provided the drinking water standards are met. The water supplier must be able to document that the Department approved the system for the higher rate.

(d) All mixed media filter beds will be at least 30 inches in depth and approved by the Department.

(e) Filtration rates above 4.0 gallons per minute per square foot will be considered on an individual basis. The Department will take into account the raw water characteristics, the treatment units, operational history, and operating personnel.

(13) All community water systems serving 50 connections or more shall install duplicate pumps for the raw water, finished water, and distribution pumping stations. A water system will not be required to have duplicate pumps in a distribution pumping station under the following conditions: limited number of service connections, availability of replacement pumps, maintaining adequate flows and pressures without the pumping station, and for emergency use only. All community public water systems using ground water supplies and having more than 50 service connections must have duplicate wells and/or duplicate pumps in a spring supply unless fed by gravity flow.

(14) All community water systems serving 50 connections or more are required to have 24 hours of distribution storage based on the average daily demand for the past twelve months. Distribution storage must be located so that the instantaneous demand can be met in all areas at any time.

(a) Systems which purchase water for resale may utilize the storage of the supplier provided the supplier has adequate distribution storage. Water systems that have large ground storage tanks will be given credit for distribution storage provided auxiliary power is available to pump water to the distribution system.

(Rule 1200-05-01-.17, continued)

(b) Systems which have more than three (3) treatment facilities, have more than one source of water, and which have special power arrangements so that it is unlikely that all units would be down at the same time are not required to have distribution storage provided the peak demand can be met.

(c) Water systems which have an average daily demand of 10 million gallons or more are not required to have 24 hours of distribution storage provided the system has adopted a contingency plan for emergencies that has been approved by the Department. The contingency plan must demonstrate the water system is able to provide residential service to all customers for a 24 hour period during any emergency involving the shut down of the treatment facility.

(d) Public water systems which utilize wells and provide only disinfection, pH adjustment, corrosion inhibitor and/or fluoridation as treatment, may use the capacity of the wells and the plant as part of the distribution storage under the following conditions:

1. The existing distribution storage tank(s) are adequate to meet the peak demands on the system,

2. The well(s), disinfection equipment and other pumping facilities needed to supply water to the distribution storage tank are equipped with an auxiliary power source with automatic controls, and

3. The well field capacity is determined by removing the largest well from consideration.

(e) Public water systems may take into account private distribution storage facilities in the following manner:

1. Private distribution storage may be counted as water system storage provided the private storage tank floats on the water utility's system and the water used serves both the private and utility system demand.

2. The water utility may reduce the amount of needed distribution storage by subtracting the average daily volume of any water user that has its own storage tank. This can be done provided the private storage tank is used on a daily basis.

3. Private distribution storage tanks used strictly for fire protection by the private owner cannot be in the water systems distribution storage capacity.

(15) All community water systems serving 50 or more service connections must have and maintain up-to-date maps of the distribution system. These maps must show the locations of the water mains, sizes of mains, valves, blow-offs or flush hydrants, air-release valves, and fire hydrants. One up-to-date copy of the overall system distribution map(s) is to be submitted to the Division of Water Supply every five years.

(16) All vents on wells, springs, storage tanks, overflows and clearwells shall be properly screened. All overflows on springs and tanks shall be screened and protected.

(17) All buildings and equipment used in and for the production and distribution of water (to include chemical and other storage buildings) must be well maintained and be reliable and fit for the purpose for which they are used. This includes, but is not limited to:

(a) When a water treatment plant is not producing water and an operator is not in attendance, plant entrances must be locked.

(Rule 1200-05-01-.17, continued)

(b) Equipment such as chemical feeders, pumps, turbidimeters, pumpage meters, alarm systems, and air tanks shall be maintained and in good working condition. Pumps, tanks, hoses, and other equipment used by system personnel shall be disinfected and dedicated to its use if it comes into contact with water that may be consumed by humans.

(c) Duplicate or backup equipment shall be available as necessary to maintain the production of water meeting drinking water standards. Backup equipment or alternate treatment means shall be available for feeding all chemicals critical for adequate water treatment.

(18) All community water systems planning to or having installed hydrants must protect the distribution system from contamination. All water mains designed for fire protection must be six inches or larger and be able to provide 500 gallons per minute with 20 pounds per square inch residual pressure. Fire hydrants shall not be installed on water mains less than six inches in diameter or on water mains that cannot produce 500 gpm at 20 psi residual pressure unless -the tops are painted red. Out of service hydrants shall have tops painted black or covered with a black shroud or tape..

Existing Class C hydrants (hydrants unable to deliver a flow of 500 gallons per minute at a residual pressure of 20 pounds per square inch (psi) shall have their tops painted red by January 1, 2008.

The water system must provide notification by certified mail at least once every five years beginning January 1, 2008, to each fire department that may have reason to utilize the hydrants, that fire hydrants with tops painted red (Class C hydrants) cannot be connected directly to a pumper fire truck. Fire Departments may be allowed to fill the booster tanks on any fire apparatus from an available hydrant by using the water system's available pressure only (fire pumps shall not be engaged during refill operations from a Class C hydrant).

(19) Before any new or modified community water treatment facility can be placed in service, it must be inspected and approved in writing by the Department.

(20) Public water systems which adjust the fluoride content of the water supply shall maintain the concentration of fluoride in the finished water between 0.9 mg/l and 1.3 mg/l based on the monthly average. Each water system adjusting the fluoride content to the finished water must monitor for fluoride as required by the system's individual monitoring program established by the Department.

(21) New or modified turbidity removal facilities may not be placed into operation until the facility and the operator have been approved by the Department for the turbidity analysis.

(22) All pipe, solder, or flux which is used in the installation or repair of any public water system shall be lead free. This shall not apply to lead joints necessary for the repair of cast iron pipes. The term "lead free" in this section is defined as follows:

(a) When used with respect to solders and flux shall mean solders and flux containing not more than two-tenths of one percent (0.2%) lead and

(b) When used with respect to pipes and pipe fittings shall mean pipes and pipe fittings containing not more than eight percent (8.0%) lead.

(23) All dead end water mains and all low points in water mains shall be equipped with a blow-off or other suitable flushing mechanism capable of producing velocities adequate to flush the main.

(Rule 1200-05-01-.17, continued)

(24) All community water systems must establish and maintain a file for customer complaints. This file shall contain the name of the person with the complaint, date, nature of complaint, date of investigation and results or actions taken to correct any problems.

(25) The Department may, upon written notice, require confirmation of any sampling results and also may require sampling and analysis for any contaminant when deemed necessary by the Department to protect the public health or welfare.

(26) Those public water systems required to monitor for turbidity and chlorine residual must have the laboratory approved by the Department before the results of these analyses can be accepted for compliance purposes.

(27) By December 30, 1991, or 18 months after the determination that a ground water system is influenced by surface water, all public water systems classified as a ground water system impacted by surface water shall utilize treatment techniques which achieve:

(a) At least 99.9 percent (3 log) removal and/or inactivation of Giardia lamblia cysts between a point where the raw water is not subject to recontamination by surface water runoff and a point downstream before or at the first customer.

(b) At least 99.99 percent (4 log) removal and/or inactivation of viruses between a point where the raw water is not subject to recontamination by surface water runoff and a point downstream before or at the first customer.

(28) All public water systems using surface water shall provide disinfection to control the biological quality of the water. Due consideration shall be given to the contact time of the disinfectant in the water with relation to pH, ammonia, taste producing substances, temperature, presence and type of pathogens, and trihalomethane formation potential. All disinfection basins must be designed to prevent water short-circuiting the system. The disinfectant will be applied in the manner needed to provide adequate contact time.

(29) All community water systems using ground water as the raw water source serving water to more than 50 connections or 150 people will apply the disinfectant in the manner needed for adequate contact time. Contact time for ground water systems shall not be less than 15 minutes prior to the first customer.

(30) Any surface supplied public water system or ground water systems under the direct influence of surface water required to filter shall employ filtration in combination with disinfection that will achieve 99.9% (3 log) and 99.99% (4 log) inactivation of Giardia lamblia and viruses respectively between a point where the raw water is not subject to recontamination by surface water runoff and a point downstream before or at the first customer. For the purposes of determining removal or inactivation efficiencies for Giardia lamblia and viruses Table 1200-05-01-.17(30)1 and 1200-05-01-.17(30)2 shall apply. The free residual disinfectant concentration in the water entering the distribution system cannot be less than 0.2 mg/l for more than four hours.

TABLE 1200-05-01-.17(30)1

ASSUMED LOG REMOVALS BY FILTRATION METHOD AND REQUIRED LEVELS OF DISINFECTION

Treatment	Assumed Log Removal		Required minimum level of disinfection	
	Giardia	Viruses	Giardia	Viruses

(Rule 1200-05-01-.17, continued)

Conventional filtration	2.5	2.0	0.5	2.0
Direct filtration	2.0	1.0	1.0	3.0
Slow Sand filtration	2.0	2.0	1.0	2.0
Diatomaceous Earth filtration	2.0	1.0	1.0	3.0

TABLE 1200-05-01-.17(30)2

CT VALUES FOR ACHIEVING 1-LOG INACTIVATION OF GIARDIA CYSTS[1]

	pH	Temperature 0.5°C	5°C	10°C	15°C
Free Chlorine [2,3]	6	55	39	29	19
	7	79	55	41	26
	8	115	81	61	41
	9	167	118	88	59
Ozone		0.97	0.63	0.48	0.32
Chlorine dioxide		1270	735	615	500

1 Values to achieve 0.5 log inactivation are one half those shown in the table.

2 CT values are for 2.0 mg/l free chlorine.

3 CT values for other concentrations of free chlorine may be taken from Appendix E of the guidance manual for Compliance with the "Filtration and Disinfection Requirements For Public Water Systems Using Surface Water Sources," October, 1989, Edition, Science and Technology Branch Criteria and Standards Division, Office of Drinking Water, USEPA, Washington, D.C.

(31) Each public water system must certify annually in writing to the State 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 ppm (or equivalent)
Epichlorohydrin = 0.01% dosed at 20 ppm (or equivalent)

Public water systems can rely on manufacturer's or third parties certification for complying with this requirement.

(32) New service taps on existing mains that must be uncovered to make the tap, shall be flushed and the free chlorine residual measured and recorded prior to connecting the service lines. These records shall be retained until the next sanitary survey or for three years.

(33) All public water systems shall properly maintain their distribution system finished water storage tanks. Each community water system shall establish and maintain a maintenance file on each of its finished water and distribution storage tanks. These maintenance files must be available for inspection by Department personnel. These files must include the dates and results of all routine water storage tank inspections by system personnel, any reports of detailed professional inspections of the water storage tanks by contractor personnel, dates and details of routine tank cleanings and surface flushings, and dates and details of all tank maintenance activities. The tank inspection records shall include dates of the inspections; the sanitary, coating and structural conditions of the tank; and all

(Rule 1200-05-01-.17, continued)

recommendations for needed maintenance activities. Community Water Systems shall have a professional inspection performed and a written report produced on each of their finished water and distribution storage tanks at least once every five years. Non-community water systems shall have a professional inspection and written report performed on each of their atmospheric pressure finished water and distribution storage tanks no less frequently than every five years. Records of these inspections shall be available to the Department personnel for inspection. Persons conducting underwater inspections of finished water storage tanks shall comply with AWWA standard C652-92 or later versions of the standard.

(34) Paints and coatings for the interior of potable water storage facilities must be acceptable to the Department. Paints and coatings accepted by the Environmental Protection Agency (EPA) and/or the National Sanitation Foundation (NSF) for potable water contact are generally acceptable to the Department. Paint systems for steel tanks shall be consistent with AWWA Standard D102-78. Factory coated bolted steel tanks shall be in accordance with AWWA D103-87. Wire-wound circular prestressed concrete tanks shall be in accordance with AWWA D110-86.

(35) By January 1, 1996, public water systems using surface water and ground water systems under the direct influence of surface water that filter shall have rewash capability. Such systems shall perform a rewash cycle, or filter to waste each time a filter is backwashed. The rewash cycle shall be conducted in a way and manner necessary to prevent the introduction of contaminants such as pathogens and turbidity trapped in the filter into the clear well or distribution system.

Existing filter plants may be approved to operate without rewash (filter-to-waste provisions) if existing operational and backwash practices prevent water of unacceptable quality from entering the clearwell or distribution system. To operate without rewash the water system must demonstrate to the Department that filtered water turbidity after backwashing is reliably and consistently below 0.5 NTU immediately after backwashing each filter. Approval to operate without rewash must be approved in writing and approval must be renewed if any modifications are made to the operation or design of the plant. Each filter that operates without rewash must have a continuous recording turbidimeter and retain the records for a period of five years.

(36) By January 1, 1995, all chemicals, additives, coatings or other materials used in the treatment, conditioning and conveyance of drinking water must have been approved by the National Sanitation Foundation (NSF) or American National Standards Institute (ANSI) certified parties as meeting NSF product standard 60 and 61. Until 1995, products used for treatment, conditioning and conveyance of drinking water shall have been listed as approved by the US EPA or NSF.

(37) Any new Community Water System or Non-Transient Non-Community Water System commencing operation after September 30, 1999 shall have a “Capacity Development Plan” and be a “viable water system.”

(38) Public Water Systems identified as not complying or potentially not complying with the requirements of the Safe Drinking Water Act and in accordance with the priorities established in the State’s Capacity Development Strategy shall prepare a “Capacity Development Plan” and demonstrate viability.

(39) Public water systems are not permitted to construct uncovered finished water reservoirs after the effective date of this subparagraph.

(40) Benchtop and continuous turbidimeters used to determine compliance with limits set forth in this rule chapter must be calibrated at least every three months with primary standards and documented. Documentation shall be maintained for a period not less than five years. Primary standards are Formazin, AMCO clear, Stablcal, or alternatives approved in writing by

(Rule 1200-05-01-.17, continued)

the Division. Dilute Formazin solutions are unstable and must be prepared on the day of calibration. Manufacturers' recommendations on calibration procedure must be followed.

(41) Verifications for benchtop turbidimeters are comparisons to approved reference materials. Verifications for continuous turbidimeters are comparisons to approved reference materials or comparisons to a properly calibrated benchtop turbidimeter. Secondary reference materials are assigned a value immediately after acceptable primary calibration has been completed. Acceptable verifications for turbidity measurements greater than 0.5 NTU must agree within ±10% from the reading assigned to the reference material after primary calibration. Acceptable verifications for measurements 0.5 NTU or less must be within ±0.05 NTU or less from the reading assigned to the reference material after primary calibration. When comparisons are made from a continuous turbidimeter to a benchtop turbidimeter, the continuous measurement must be within ±10% of the benchtop reading for measurements above 0.5 NTU and ±0.05 NTU for reading 0.5 NTU or less. When acceptable verifications are not achieved the instrument must be re-calibrated with primary standards according to paragraph (40) of this rule. Approved reference materials for benchtop turbidimeters are primary standards and materials suggested by the manufacturer such as sealed sample cells filled with metal oxide particles in a polymer gel. The 0.5 NTU ICE-PIC™ from Hach is an approved reference material for secondary turbidity verifications for Hach continuous turbidimeters when utilized as per Manufacturers' recommendations. All other reference materials for turbidimeter verifications must be approved in writing by the Division. Verifications for turbidimeters must be performed according to the following:

(a) Verification of benchtop turbidimeters must be performed daily and documented. Verifications must include a sample in the expected working range of the instrument or as close to the working range as possible. Documentation must include: assigned reference material value after calibration, recorded daily reading for all reference standards, instrument identification, and date.

(b) Combined filter effluent turbidimeters as required by Rule 1200-05-01-.31(5)(c)1. must be verified daily and documented. When reference material is utilized documentation must include: instrument identification, date, assigned reference material value after calibration, and daily value for reference material. When comparisons to benchtop turbidimeters are utilized documentation must include: instrument identification, date, continuous turbidimeter value, and benchtop turbidimeter value.

(c) Individual filter turbidimeters as required by Rule 1200-05-01-.31(5)(c)4. must be verified weekly.

Authority: *T.C.A. §§4-5-201 et seq., 4-5-202, 68-221-701 et seq., and 68-221-704.* ***Administrative History:*** *Original rule filed June 30, 1977; effective August 1, 1977. Amendment filed February 3, 1984; effective February 12, 1985. Amendment filed September 26, 1988; effective November 10, 1988. Amendment filed November 26, 1990; effective January 10, 1991. Amendment filed August 24, 1992; effective October 8, 1992. Amendment filed October 22, 1993; effective January 5, 1994. Amendment filed April 12, 1996; effective June 26, 1996. Amendment filed February 17, 1999; effective May 3, 1999. Amendment filed October 31, 2000; effective January 14, 2001. Amendment filed November 21, 2001; effective February 4, 2002. Amendment filed December 30, 2002; effective March 15, 2003. Amendments filed August 15, 2005; effective October 29, 2005. Amendments filed June 12, 2008; effective August 26, 2008. Amendments filed March 23, 2009; effective June 6, 2009.*

1200-05-01-.18 REPORTING REQUIREMENTS.

(1) Except where a shorter period is specified in this Chapter, the supplier of water shall report to the Department the results of any test measurement or analysis required by this part within (A) the first ten days following the month in which the result is received or (B) the first ten days following the end of the required monitoring period as stipulated by the Department, which ever of these is shortest.

(Rule 1200-05-01-.18, continued)

(b) Report any data or information that is inaccurate, misleading or false because the person reporting has not used reasonable care, judgment or the application of his knowledge in the preparation of the report.

(c) Provide inaccurate or false statements to the State.

Authority: *T.C.A. §§4-5-201 et seq., 4-5-202, 68-13-704, 68-221-701 et seq., and 68-221-704.* ***Administrative History:*** *Original rule. filed June 30, 1977; effective August 1, 1977. Amendment filed February 3, 1984; effective February 12, 1985. Amendment filed September 26, 1988; effective November 10, 1988. Amendment filed August 24, 1992; effective October 8, 1992. Amendment filed November 21, 2001; effective February 4, 2002. Amendments filed June 12, 2008; effective August 26, 2008.*

1200-05-01-.19 NOTIFICATION OF CUSTOMERS.

(1) Each owner and operator of a public water system including community, non-transient non-community, and non-community water systems must comply with this rule.

(a) Each owner or operator of a public water system must give public notice for all violations of national primary drinking water regulations and for other situations as listed in Table 1200-05-01-.19(1). The term national primary drinking water regulation is used in this rule to include violations of the maximum contaminant level (MCL), maximum residual disinfectant level (MRDL), treatment technique (TT), monitoring requirements, and testing procedures described in these regulations. Appendix A to this rule identifies the tier assignment for each specific violation or situation requiring a public notice.

Table 1200-05-01-.19(1)
Violation Categories and Other Situations
Requiring a Public Notice

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1. NPDWR violations:

(i) Failure to comply with an applicable maximum contaminant level (MCL) or maximum residual disinfectant level (MRDL).
(ii) Failure to comply with a prescribed treatment technique (TT).
(iii) Failure to perform water quality monitoring, as required by the drinking water regulations.
(iv) Failure to comply with testing procedures as prescribed by a drinking water regulation.

2. Variance and exemptions under sections 1415 and 1416 of SDWA:

(i) Operation under a variance or an exemption.
(ii) Failure to comply with the requirements of any schedule that has been set under a variance or exemption.

3. Special public notices:

(i) Occurrence of a waterborne disease outbreak or other waterborne emergency.
(ii) Exceedance of the alternate MCL for nitrate by non-community water systems (NCWS), where the non-community system has been granted an alternate standard by the department.
(iii) Exceedance of the secondary maximum contaminant level (SMCL) for fluoride.
(iv) Availability of unregulated contaminant monitoring data.
(v) Other violations and situations determined by the department to require a public notice under this rule, not already listed in Appendix A.

(Rule 1200-05-01-.19, continued)

(b) Public notice requirements are divided into three tiers to take into account the seriousness of the violation or situation and any potential adverse health effects that may be involved. The public notice requirements for each violation or situation listed in Table 1 of this section are determined by the tier to which it is assigned. Table 1200-05-01-.19(1)(b)2 of this paragraph provides the definition of each tier. Appendix A of this rule identifies the tier assignment for each specific violation or situation.

Table 1200-05-01-.19(1)(b)2
Definition of Public Notice Tiers

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1. Tier 1 public notice--required for NPDWR violations and situations with significant potential to have serious adverse effects on human health as a result of short-term exposure.

2. Tier 2 public notice--required for all other NPDWR violations and situations with potential to have serious adverse effects on human health.

3. Tier 3 public notice--required for all other NPDWR violations and situations not included in Tier 1 and Tier 2.

(c) Who must be notified?

1. Each public water system must provide public notice to persons served by the water system, in accordance with this rule. Public water systems that sell or otherwise provide drinking water to other public water systems (i.e., to consecutive systems) are required to give public notice to the owner or operator of the consecutive system; the consecutive system is responsible for providing public notice to the persons it serves.

2. If a public water system has a violation in a portion of the distribution system that is physically or hydraulically isolated from other parts of the distribution system, the Division may allow the system to limit distribution of the public notice to only persons served by that portion of the system which is out of compliance. Permission by the department for limiting distribution of the notice must be granted in writing.

3. A representative copy of the each type of the notice distributed, published, posted and/or made available to the persons served by the system and/or to the media must also be sent to the Division within ten days of completion of each public notification.

(2) Tier 1 Public Notice--Form, manner, and frequency of notice.

(a) Which violations or situations require a Tier 1 public notice? Table 1200-05-01-.19(2) of this paragraph lists the violation categories and other situations requiring a Tier 1 public notice. Appendix A to this rule identifies the tier assignment for each specific violation or situation.

Table 1200-05-01-.19(2) Violation Categories and Other Situations
Requiring a Tier 1 Public Notice

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1. Violation of the MCL for total coliforms when fecal coliform or E. coli are present in the water distribution system as specified in 1200-05-01-.06, or when the water system fails to test for fecal coliforms or E. coli when any repeat sample tests positive for coliform as specified in 1200-05-01-.07;

(Rule 1200-05-01-.19, continued)

2. Violation of the MCL for nitrate, nitrite, or total nitrate and nitrite, as defined in 1200-05-01-.06, or when the water system fails to take a confirmation sample within 24 hours of the system's receipt of the first sample showing an exceedance of the nitrate or nitrite MCL, as specified in 1200-05-01-.09;

3. Exceedance of the alternate MCL for nitrate by non-community water systems (NCWS), where the non-community system has been granted an alternate standard by the department;

4. Violation of the MRDL for chlorine dioxide, as defined in 1200-05-01-.36, when one or more samples taken in the distribution system the day following an exceedance of the MRDL at the entrance of the distribution system exceed the MRDL, or when the water system does not take the required samples in the distribution system, as specified in 1200-05-01-.36;

5. Violation of the turbidity MCL under 1200-05-01-.06, where the department determines after consultation that a Tier 1 notice is required or where consultation does not take place within 24 hours after the system learns of the violation;

6. Violation of the Surface Water Treatment Rule (SWTR) 1200-05-01-.31, Interim Enhanced Surface Water Treatment Rule (IESWTR) or Long Term 1 Enhanced Surface Water Treatment Rule (LT1ESWTR) treatment technique requirement resulting from a single exceedance of the maximum allowable turbidity limit (as identified in Appendix A) where the department determines after consultation that a tier 1 notice is required or where consultation does not take place within 24 hours after the system learns of the violation;

7. Occurrence of a waterborne disease outbreak, as defined in 1200-05-01-.04, or other waterborne emergency (such as a failure or significant interruption in key water treatment processes, a natural disaster that disrupts the water supply or distribution system, or a chemical spill or unexpected loading of possible pathogens into the source water that significantly increases the potential for drinking water contamination);

8. Other violations or situations with significant potential to have serious adverse effects on human health as a result of short-term exposure, as determined by the Division either in its regulations or on a case-by-case basis.

9. Detection of E. coli or enterococci in source water samples as specified in Rule 1200-05-01-.40(3).

(b) When is the Tier 1 public notice to be provided? What additional steps are required? Public water systems must:

1. Provide a public notice as soon as practical but no later than 24 hours after the system learns of the violation;

2. Initiate consultation with the Division agency as soon as practical, but no later than 24 hours after the public water system learns of the violation or situation, to determine additional public notice requirements; and

3. Comply with any additional public notification requirements (including any repeat notices or direction on the duration of the posted notices) that are established as a result of the consultation with the Division. Such requirements may include the timing, form, manner, frequency, and content of repeat notices (if any) and other actions designed to reach all persons served.

(c) What is the form and manner of the public notice? Public water systems must provide the notice within 24 hours in a form and manner reasonably calculated to reach all persons served. The form and manner used by the public water system are to fit the

(Rule 1200-05-01-.19, continued)

specific situation, but must be designed to reach residential, transient, and non-transient users of the water system. In order to reach all persons served, water systems are to use, at a minimum, one or more of the following forms of delivery:

1. Appropriate broadcast media (such as radio and television);

2. Posting of the notice in conspicuous locations throughout the area served by the water system;

3. Hand delivery of the notice to persons served by the water system; or

4. Another delivery method approved in writing by the department.

(3) Tier 2 Public Notice--Form, manner, and frequency of notice.

(a) Which violations or situations require a Tier 2 public notice? Table 1200-05-01-.19(3) of this paragraph lists the violation categories and other situations requiring a Tier 2 public notice. Appendix A to this rule identifies the tier assignment for each specific violation or situation.

Table 1200-05-01-.19(3) Violation Categories and Other Situations Requiring a Tier 2 Public Notice

---

1. All violations of the MCL, MRDL, and treatment technique requirements, except where a Tier 1 notice is required under subparagraph (2)(a) or where the department determines that a Tier 1 notice is required;

2. Violations of the monitoring and testing procedure requirements, where the department determines that a Tier 2 rather than a Tier 3 public notice is required, taking into account potential health impacts and persistence of the violation; and

3. Failure to comply with the terms and conditions of any variance or exemption in place.

4. Failure to take corrective action or failure to maintain at least 4-log treatment of viruses (using inactivation, removal, or a Department-approved combination of 4-log virus inactivation and removal) before or at the first customer under Rule 1200-05-01-.40(4)(a).

(b) When is the Tier 2 public notice to be provided?

1. Public water systems must provide the public notice as soon as practical, but no later than 30 days after the system learns of the violation. If the public notice is posted, the notice must remain in place for as long as the violation or situation persists, but in no case for less than seven days, even if the violation or situation is resolved. The department may, in appropriate circumstances, allow additional time for the initial notice of up to three months from the date the system learns of the violation. The department will not grant an extension to the 30-day deadline for any unresolved violation or to allow across-the-board extensions by rule or policy for other violations or situations requiring a Tier 2 public notice. Extensions granted by the department must be in writing.

2. The public water system must repeat the notice every three months as long as the violation or situation persists, unless the department determines that appropriate circumstances warrant a different repeat notice frequency. In no circumstance may the repeat notice be given less frequently than once per year. The department will not allow less frequent repeat notice for an MCL violation under the Total Coliform Rule or a treatment technique violation under the 1200-

(Rule 1200-05-01-.19, continued)

56-01-.31. The department will not through its rules or policies permit across-the-board reductions in the repeat notice frequency for other ongoing violations requiring a Tier 2 repeat notice. Departmental determinations allowing repeat notices to be given less frequently than once every three months must be in writing.

3. For the turbidity violations specified in this paragraph, public water systems must consult with the division agency as soon as practical but no later than 24 hours after the public water system learns of the violation, to determine whether a Tier 1 public notice under 1200-05-01-.19(2)(a) is required to protect public health. When consultation does not take place within the 24-hour period, the water system must distribute a Tier 1 notice of the violation within the next 24 hours (i.e., no later than 48 hours after the system learns of the violation), following the requirements under 1200-05-01-.19(2)(b) and (c). Consultation with the department is required for:

(i) Violation of the turbidity MCL under 1200-05-01-.06; or

(ii) Violation of the SWTR, IESWTR or LT1ESWTR treatment technique requirement (1200-05-01-.31) resulting from a single exceedance of the maximum allowable turbidity limit.

(c) What is the form and manner of the Tier 2 public notice? Public water systems must provide the initial public notice and any repeat notices in a form and manner that is reasonably calculated to reach persons served in the required time period. The form and manner of the public notice may vary based on the specific situation and type of water system, but it must at a minimum meet the following requirements:

1. Unless directed otherwise by the department in writing, community water systems must provide notice by:

(i) Mail or other direct delivery to each customer receiving a bill and to other service connections to which water is delivered by the public water system; and

(ii) Any other method reasonably calculated to reach other persons regularly served by the system, if they would not normally be reached by the notice required in subparagraph (c)1(i) of this paragraph. Such persons may include those who do not pay water bills or do not have service connection addresses (e.g., house renters, apartment dwellers, university students, nursing home patients, prison inmates, etc.). Other methods may include: publication in a local newspaper; delivery of multiple copies for distribution by customers that provide their drinking water to others (e.g., apartment building owners or large private employers); posting in public places served by the system or on the Internet; or delivery to community organizations.

2. Unless directed otherwise by the department in writing, non-community water systems must provide notice by:

(i) Posting the notice in conspicuous locations throughout the distribution system frequented by persons served by the system, or by mail or direct delivery to each customer and service connection (where known); and

(ii) Any other method reasonably calculated to reach other persons served by the system if they would not normally be reached by the notice required in subparagraph (c)2(i). Such persons may include those served who may

(Rule 1200-05-01-.19, continued)

not see a posted notice because the posted notice is not in a location they routinely pass by. Other methods may include: publication in a local newspaper or newsletter distributed to customers; use of E-mail to notify employees or students; or, delivery of multiple copies in central locations (e.g., community centers).

(4) Tier 3 Public Notice--Form, manner, and frequency of notice.

(a) Which violations or situations require a Tier 3 public notice? Table 1200-05-01-.19(4) of this paragraph lists the violation categories and other situations requiring a Tier 3 public notice. Appendix A to this subpart identifies the tier assignment for each specific violation or situation.

Table 1200-05-01-.19(4)
Violation Categories and Other Situations Requiring a Tier 3 Public Notice

1. Monitoring violations for the primary drinking water contaminants, except where a Tier 1 notice is required under 1200-05-01-.19(2)(a) or where the department determines that a Tier 2 notice is required;

2. Failure to comply with an approved departmental or EPA testing procedure, except where a Tier 1 notice is required under 1200-05-01-.19(2)(a) or where the department determines that a Tier 2 notice is required;

3. Operation under a variance granted under Section 1415 or an exemption granted under Section 1416 of the Safe Drinking Water Act;

4. Availability of unregulated contaminant monitoring results, as required under 1200-05-01-.19(7), and

5. Exceedance of the fluoride secondary maximum contaminant level (SMCL), as required under 1200-05-01-.19(8).

(b) When is the Tier 3 public notice to be provided?

1. Public water systems must provide the public notice not later than one year after the public water system learns of the violation or situation or begins operating under a variance or exemption. Following the initial notice, the public water system must repeat the notice annually for as long as the violation, variance, exemption, or other situation persists. If the public notice is posted, the notice must remain in place for as long as the violation, variance, exemption, or other situation persists, but in no case less than seven days (even if the violation or situation is resolved).

2. Instead of individual Tier 3 public notices, a public water system may use an annual report detailing all violations and situations that occurred during the previous twelve months, as long as the timing requirements of subparagraph (b)1 of this paragraph are met.

(c) What is the form and manner of the Tier 3 public notice? Public water systems must provide the initial notice and any repeat notices in a form and manner that is reasonably calculated to reach persons served in the required time period. The form and manner of the public notice may vary based on the specific situation and type of water system, but it must at a minimum meet the following requirements:

(Rule 1200-05-01-.19, continued)

1. Unless directed otherwise by the division in writing, community water systems must provide notice by:

   (i) Mail or other direct delivery to each customer receiving a bill and to other service connections to which water is delivered by the public water system; and

   (ii) Any other method reasonably calculated to reach other persons regularly served by the system, if they would not normally be reached by the notice required in subparagraph (c)1(i) of this paragraph. Such persons may include those who do not pay water bills or do not have service connection addresses (e.g., house renters, apartment dwellers, university students, nursing home patients, prison inmates, etc.). Other methods may include: Publication in a local newspaper; delivery of multiple copies for distribution by customers that provide their drinking water to others (e.g., apartment building owners or large private employers); posting in public places or on the Internet; or delivery to community organizations.

2. Unless directed otherwise by the division in writing, non-community water systems must provide notice by:

   (i) Posting the notice in conspicuous locations throughout the distribution system frequented by persons served by the system, or by mail or direct delivery to each customer and service connection (where known); and

   (ii) Any other method reasonably calculated to reach other persons served by the system, if they would not normally be reached by the notice required in subparagraph (c)2(i) of this paragraph. Such persons may include those who may not see a posted notice because the notice is not in a location they routinely pass by. Other methods may include: Publication in a local newspaper or newsletter distributed to customers; use of E-mail to notify employees or students; or, delivery of multiple copies in central locations (e.g., community centers).

(d) In what situations may the Consumer Confidence Report be used to meet the Tier 3 public notice requirements? For community water systems, the Consumer Confidence Report (CCR) may be used as a vehicle for the initial Tier 3 public notice and all required repeat notices, as long as:

1. The CCR is provided to persons served no later than 12 months after the system learns of the violation or situation as required under 1200-05-01-.19(4)(b);

2. The Tier 3 notice contained in the CCR follows the content requirements under 1200-05-01-.19(5); and

3. The CCR is distributed following the delivery requirements under 1200-05-01-.19(4)(c).

(5) Content of the public notice.

(a) What elements must be included in the public notice for violations of National Primary Drinking Water Regulations (NPDWR) or other situations requiring a public notice? When a public water system violates a NPDWR or has a situation requiring public notification, each public notice must include the following elements:

1. A description of the violation or situation, including the contaminant(s) of concern, and (as applicable) the contaminant level(s);

Rules and Regulations

Types of Regulations	Title	Rules or Law Designation
Rules of the TN Dept of Health and TDEC	http://www.state.tn.us/sos/rules/1200/1200.htm	
Rules of TDEC - Groundwater	Subsurface Sewage Disposal	1200-1-6
Rules of TDEC – Water Pollution	General Rules	1200-4-1
"	Plans Submittal	1200-4-2
"	Water Quality Criteria	1200-4-3
"	Stream Use Classifications	1200-4-4
"	Effluent Limits and Standards	1200-4-5
"	APAP	1200-4-7
"	Stormwater	1200-4-10
"	Environmental Protection Fees	1200-4-11
Rules of TDEC – Certification	Board of Certified Operators	1200-5-3
Rules of TWRA	Marine Sanitation	1660-2-11
Tennessee Water Quality Control Act	http://www.state.tn.us/environment/wpc/publicat.htm	
Law of TN – Groundwater	Subsurface Disposal Systems	T.C.A. 68-13-401 et. seq.
Law of TN – Water Supply	Safe Drinking Water	T.C.A. 68-13-701 et. seq.
Law of TN – Certification	Water Environmental Health	T.C.A. 68-221-901 et. seq.
Law of TN – Water Pollution	Water Quality Control	T.C.A. 68-3-101 et. seq.
Code of Federal Regulations	http://www.gpoaccess.gov/cfr/index.html	
Federal Law – OSHA	Confined Space Entry	29 CFR 1910
Federal Law – EPA	Bulk Oil Storage Facilities	40 CFR 112
Federal Law – EPA	Guidelines Establishing Test Procedures for the Analysis of Pollutants	40 CFR 136
Federal Law – EPA	Standards for Sludge Disposal	40 CFR 503

Public Notification Exercise

Identify:

1. Tier 1:

2. Tier 2:

3. Tier 3:

Instructions: List what Tier of PN you would take with each situation listed below, no PN can be a result also:

1. The contract laboratory has reported the fluoride result as 4.1 mg/L.

2. The system has received a positive result on Fecal coliform on analysis after a positive total coliform repeat sample.

3. The contract lab has notified the system that the samples submitted for TMH's were analyzed after the holding times had expired. The specific monitoring period has also passed. The lab sent the results to the system two weeks prior to their discovery of the holding time error. This result has already been reported to the state.

4. A system has been notified by their lab that the Alachlor level was 0.001mg/L.

5. A small system must collect two total coliform samples per month, but failed to do so last month.

6. The analysis for nitrate was 10.5 mg/L. A confirmation sample was collected within 24 hours. Its value was 9.3 mg/L.

7. The free chlorine residual is 5.0 mg/L in the distribution system.

8. A system had one positive total coliform sample during the month. All the repeat samples and distribution samples were negative for the month.

9. A system has a sodium level of 5.9 mg/L.

10. A water system had one positive total coliform test and one positive total coliform on a repeat sample during the same month.

11. The contract laboratory has reported the fluoride result as 3.7 mg/L.

12. A system that collects 60 samples per month had four positive total coliform samples during the month. All the repeat samples and distribution samples were negative for the month.

13. A system has been notified by their lab that the Dioxin level was 0.0000001mg/L.

Answers

Identify:

1. **violations and situations with significant potential to have serious adverse effects on human health as a result of short-term exposure**
2. **public notice – required for all other NPDWR violations and situations with potential to have serious adverse effects on human health**
3. **public notice – required for all other NPDWR violations and situations not included in Tier 1 and Tier 2**

Instructions: List what Tier of PN you would take with each situation listed below, no PN can be a result also:

4. **Tier 2 (Tier 3 if between 2-4 mg/L)**
5. **Tier 1**
6. **Tier 2 (Tier 3 if not reported to State)**
7. **NO PN, below MCL**
8. **Tier 3 (Tier 2 if chronic problem)**
9. **No PN because avg. samples = 9.9 mg/L < MCL**
10. **Tier 2**
11. **NO PN, can have 5%**
12. **NO PN, but notify State within 10 days, page 97**
13. **Tier 2**
14. **Tier 3**
15. **Tier 2**
16. **Tier 2**

Rules and Regulation Exercise

Definitions:

1) Define a Subpart H system.

2) Define public water system.

MCL's

3) The contract laboratory has reported this data (are these violations and if so, what is the MCL?):

a) arsenic level at 0.05 mg/L.

b) nitrate level at 12 mg/L.

c) fluoride level at 4.3 mg/L.

d) atrazine level at 0.005 mg/L.

e) lindane level at 0.005 mg/L.

f) chromium level at 0.4 mg/L.

g) THM level at 0.09mg/L.

h) HAA5 level at 0.55 mg/L.

i) chlorine level at 4.3 mg/L.

j) chlorine dioxide level at 0.79 mg/L.

k) chloramine level at 3.9 mg/L.

l) fecal coliform-positive repeat sample

m) E. coli-positive repeat sample

n) Total coliform-positive repeat sample following a fecal coliform-positive or E. coli-positive routine sample

4) **The maximum contaminant levels for turbidity in drinking water, measured at a representative entry point(s) to the distribution system are ___________ NTU as determined by monthly average pursuant or ___________ NTU based on an average for two consecutive days.**

5) **The maximum contaminant level for microbiologicals are based on the presence or absence of total coliforms, these numbers shall not exceed any of the following:**

    a) **A system that collects at least __________ samples per month shall have no more than __________ % samples that are total coliform positive.**

    b) **A system that collects fewer than __________ shall have no more than __________ sample collected for the month that are total coliform positive.**

Sampling

6) **You serve a community of 32,000 people, how many samples would you need to collect per month for total coliform?**

7) **You serve a community of 8,200 people, how many samples would you need to collect per month for total coliform?**

8) **If a routine sample is total coliform-positive, you must collect a set of repeat samples within __________ hours of being notified of the positive result. The system must collect at least __________ repeat sample from the sampling tap where the original total coliform-positive sample was taken, and at least __________ repeat sample at a tap within __________ service connections upstream and at a tap within __________ service connections downstream of the original sampling site.**

9) **Turbidity measurements must be performed on representative samples of the system's filtered water every __________ hours.**

Operation and Maintenance Requirements

10) **All community water systems that are designed as a __________ supply and classified as a __________ system and all __________ removal plants that use gravity filters must have an __________ in attendance and responsible for the treatment process when the plant is in __________ .**

11) **Daily operating records shall be submitted so the Department receives them no later than __________ after the end of the reporting month.**

12) **All water quality tests shall be made in accordance with the latest edition of ____ or alternate methods acceptable to the Department.**

13) Free chlorine levels in the distribution system shall be maintained at no less than _________.

14) All community water systems shall develop a written plan for a _______________ control program to detect and eliminate or protect the system from _______________.

15) Newly constructed or repaired water distribution lines, finished water storage facilities, filters and wells shall be flushed and disinfected in accordance with ________________ ____.

16) All community water systems shall be operated and maintained to provide a minimum positive pressure of ___________ psi throughout the distribution system.

17) All community water systems having more than 50 service connections shall establish and maintain an adequate ___________ program. Records must be maintained and shall include:

a) ________________________

b) ________________________

c) ________________________

d) ________________________

e) _______________________

18) All community public water systems serving more than 50 service connections and that have their own source of water shall be required to install, operate and maintain __________ disinfection equipment.

19) What is the filtration rate of a high rate filter?

20) How many inches of media are required?

a) Dual media:

i) Sand:

ii) Anthracite:

b) Mixed media beds:

21) All community water systems serving 50 connections or more are required to have __________ hours of distribution storage based on the __________ __________ demand for the past __________ months.

22) All community water systems serving 50 or more service connections must have and maintain up-to-date __________ of the distribution system. These maps must show the locations of the:

a) ________________________ **d)** ________________________

b) ________________________ **e)** ________________________

c) ________________________ **f)** ________________________

23) All vents on __________, springs, __________ __________, overflows and __________ shall be properly screened.

24) All community water systems planning to provide fire protection must have the distribution system designed to provide fire flow. All water mains designed for fire protection must be __________ inches or larger and be able to provide __________ gpm with ___________ psi.

25) Public water systems that adjust the fluoride levels shall maintain the concentration of fluoride in the finished water between __________ mg/L and __________ mg/L.

26) All community water systems must establish and maintain a file for customer complaints. This file should include:

a) ________________________ **c)** ________________________

b) ________________________ **d)** ________________________

e) ____

27) Any surface supplied public water system or ground water systems under the direct influence of surface water required to filter shall employ filtration in combination with disinfection that will achieve __________% (_____ log) and __________% (______ log) inactivation of Giardia lamblia and viruses respectively between a point where the raw water is not subject to recontamination by surface water runoff and a point downstream before or at the fist customer.

Rules and Regulation Exercise

Definitions:

1) Public water systems using surface water or ground water under the direct influence of surface water as a source that are subject to the requirements of filtration. 1200-5-1-.04(87)

2) A system for the provision of piped water for human consumption if such serves 15 or more connections or which regularly serves 25 or more individuals daily at least 60 days out of the year. 1200-5-1-.04(75)

MCL's

3)

- **a) arsenic level at 0.05 mg/L.** MCL is 0.05 mg/L **until 1/06, then 0.01 mg/L**
- **b) nitrate level at 12 mg/L.** MCL is 10 mg/L
- **c) fluoride level at 4.3 mg/L.** MCL 4.0 mg/L
- **d) atrazine level at 0.005 mg/L.** MCL is 0.003 mg/L
- **e) lindane level at 0.005 mg/L.** MCL is 0.0002 mg/L
- **f) chromium level at 0.4 mg/L.** MCL is 0.1 mg/L

1200-5-1-.06 (1)(b) and (2)(a)

- **g) THM level at 0.09mg/L.** MCL is 0.08 mg/L
- **h) HAA5 level at 0.55 mg/L.** MCL is 0.06 mg/L
- **i) chlorine level at 4.3 mg/L.** MCL is 4.0 mg/L
- **j) chlorine dioxide level at 0.79 mg/L.** MCL is 0.8 mg/L
- **k) chloramine level at 3.9 mg/L.** MCL is 4.0 mg/L

1200-5-1-.06 (6)(b) and (6)(c)

- **l) fecal coliform-positive repeat sample** violation
- **m) E. coli-positive repeat sample** violation
- **n)** violation

1200-5-1-.06 (4)

4) 1.0 **and** 2.0 - Page 16, 1200-5-1-.06(3)

5) a) 40 **and** 5 , 1200-5-1-.06(4)(a)(1); **b)** 40 **and** 1, 1200-5-1-.06(4)(a)(1)

Sampling

6) 30, 1200-5-1-.07(1)(c)

7) 9, 1200-5-1-.07(1)(c)

8) 24, 1, 1, 5, 5; 1200-5-1-.07(2)(a) and (b)

9) 4, 1200-5-1-.08(2)(a)

Operation and Maintenance Requirements

10) surface, filtration, iron, operator, operation; 1200-5-1-.17(1)

11) 10 days; 1200-5-1-.17(2)

12) "Standard Methods for the Examination of Water and Wastewater"; 1200-5-1-.17(3)

13) 0.2 mg/L; 1200-5-1-.17(4)

14) cross-connection, cross-connections; 1200-5-1-.17(6)

15) AWWA standards C-651, C-652 or equivalent methods provided the method has been approved in writing by the department and is available during the inspection, construction, maintenance or repair activity; 1200-5-1-.17(8)(a)

16) 20; 1200-5-1-.17(9)

17) flushing; **a)** date, **b)** time, **c)** location, **d)** persons responsible, **e)**length of flushing; 1200-5-1-.17(10)

18) duplicate; 1200-5-1-.17(11)

19) 4.0 gpm per square foot; 1200-5-1-.17(12)(b)

20) **a) Dual media:** 30 inches, **i) Sand:** 10-12 inches, **ii) Anthracite:** 18-20 inches, **b) Mixed media beds:** 30 inches; 1200-5-1-.17(12)(b) and (d)

21) 24, average daily, 12; 1200-5-1-.17(14)

22) maps; **a)** water mains, **b)** sizes of mains, **c)** valves, **d)** blow-offs or flush hydrants, **e)** air-release valves, **f)** fire hydrants; 1200-5-1-.17(15)

23) wells, storage, tanks, clearwells; 1200-5-1-.17(16)

24) 6, 500, 20; 1200-5-1-.17(18)

25) 0.9, 1.3; 1200-5-1-.17(20)

26) **a)**name of person with complaint, **b)** date, **c)** nature of complaint, **d)** date of investigation, **e)**results or actions taken to correct any problems

27) 99.9, 3, 99.99, 4; 1200-5-1-.17(27)(a) and (b)

Section 14

Hydrant Flushing

Water Main Flushing Program

Fleming Training Center

TDEC - Fleming Training Center 1

Flushing Program

- Why do we do this?
  - Important preventative maintenance
    - •Removes particulate matter and corrosion from lines
  - Improve water quality
    - •Low chlorine residual
    - •Brown water
    - •Positive bacterial counts
    - •Poor taste
    - •Bad odor
  - Customer complaints
    - •Taste and odor problems
    - •Turbid or colored water
    - •Reduced pressure
  - Basically it improves overall water quality

TDEC - Fleming Training Center 2

Flushing Programs

- How frequently should you flush?
  - Surface waters systems are usually going to flush more often due to increased nutrients in the water
  - Water quality indicators can be used to increase flushing:
    - Temperature, increase
    - Chlorine residual, decrease
    - Corrosion inhibitor, decrease
    - pH, decrease
    - Taste and odor, increase in complaints

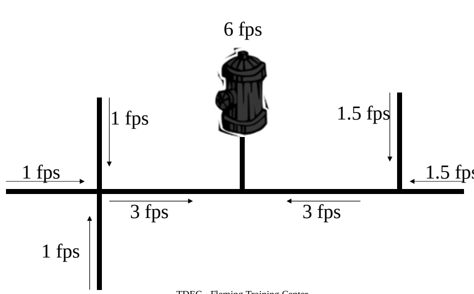
TDEC - Fleming Training Center 3

Flushing Program

- 2 types:
  - Unidirectional
    - water system valves are operated to create a one-way flow of the water, this increases the speed and scours the lines removing biofilm and corrosion
  - Conventional
    - the water used to flush the main does not always begin at a clean water source and the speed is low therefore more water is needed to clean mains

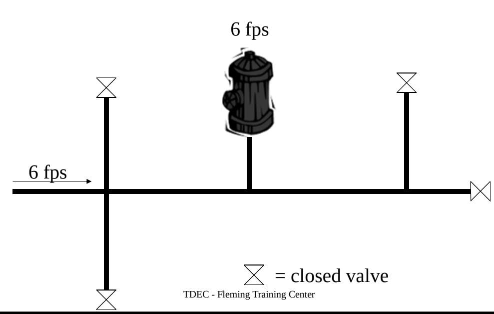
TDEC - Fleming Training Center 4

Conventional Flushing



TDEC - Fleming Training Center 5

Unidirectional Flushing



TDEC - Fleming Training Center 6

Unidirectional Flushing

- Needs some engineering
- You control
  - flow
  - direction
    - where the water is coming from and where it is going
- You have to know your distribution system
  - know location of all mains, valves and hydrants

TDEC - Fleming Training Center 7

Unidirectional Flushing

- Pros
  - uses 40% less water than conventional flushing
  - scours and cleans pipes up to 2 years
  - more localized
  - tests most valves and hydrants
    - identifies those that need repair or replacement

TDEC - Fleming Training Center 8

Unidirectional Flushing

- Requirements:
  - Distribution maps and plans
  - Chart flow directions
  - Examine depletion and replenishment patterns of storage tanks
  - Review components
    - tanks, hydrants, blow off valves, pipe material and pump stations

TDEC - Fleming Training Center 9

Unidirectional Flushing

- Divide into sections (manageable loops) that will be flushed in sequence
  - flushing runs
  - set target for flushing velocities 2-5 fps
    - remove biofilm
    - doesn't stress weak areas
- Develop step-by-step flushing sequence
  - which hydrant or blow off valve to open and which valve to open or close

TDEC - Fleming Training Center 10

Unidirectional Flushing

- Start from beginning - treatment plant or storage tank
- Isolate pipes you want to flush - close valves
- Flush from clean to dirty pipes
- Force water from bigger main to smaller main
- Sample water before, during and after

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Unidirectional Flushing

- Safety
  - use a diffuser to decrease water velocity
  - dechlorinate if there's a chance of getting into surface water
  - open valves and close them slowly so you don't create water hammer
  - wear appropriate clothing so people will see you
  - watch traffic
  - be careful when flushing hydrant, you don't know what could come out of it

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Unidirectional Flushing

- Restored disinfectant residual
- Reduces disinfectant demand
- Reduces bacterial growth
- Dislodges biofilms
- Removes sediments and deposits
- Restores flows and pressures
- Eliminates taste and odor problems

Documentation

- You should document each time you flush a line
  - location
  - beginning of flush
    - color of water
    - residual chlorine
  - end of flush
    - color of water
    - residual chlorine
  - time flushed
  - rate of flow

Notify Customers

- You should notify your customers that you will be flushing lines in their area
  - bill stuffers
  - media - news papers, new stations
- They should be told that their water may be discolored but to let their cold water run until water is clear
  - they shouldn't use colored water for laundry, cooking or drinking
  - don't use hot water to flush lines; they could end up with colored water getting into their water heaters

Flushing Program Record

Date	Time	Location or Address	Type of Valve or Hydrant	Time to Clear	Total Time	Flow (gpm)	Free Chlorine Residual	Persons Responsible

Section 15

Taste and Odor

Significance
Sampling
Methods of Determination
Methods of Removing

TASTE AND ODOR

Taste and Odor

- There are few, if any, enforceable regulations worldwide regarding taste and odor compounds in drinking water
- They have the status of "Secondary Standards"

Taste and Odor

- Customers expect their tap water to taste and smell good
- The problem is that if there is a taste or odor problem present, your customer associates this with unsafe drinking water

Taste and Odor

- This lack of trust has resulted in dramatic increase in the use of bottled water

Taste and Odor

- Aesthetic qualities of drinking water and their measures are dependent on human perception
- Difficult to measure
- Caused by a variety of substances
  - Organic matter
  - Dissolved gases
  - Industrial waste
  - Leached metals

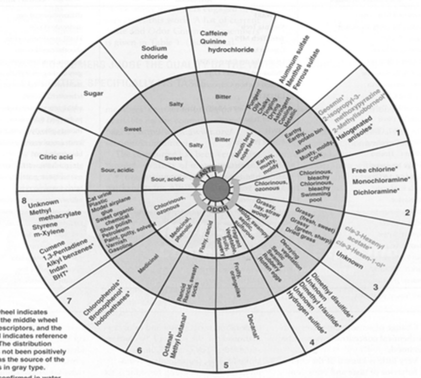
Taste and Odor

- The exact cause of taste and odor problems must be identified, whether it is source contamination, microbial metabolites, chemicals produced during treatment or chemicals produced in the distribution system, in order to minimize the problem

Taste and Odor

- Since researchers have been able to identify causes of taste and odor problems, control methods can be used to improve the aesthetic quality of drinking water
- This means happier customers ☺

FIGURE 1 Wheel identifying distribution system–generated tastes and odors



The inner wheel indicates categories, the middle wheel indicates descriptors, and the outer wheel indicates reference standards. The distribution system has not been positively confirmed as the source of the compounds in gray type.

*Presence confirmed in water

Source: D. Khiari et al, 2002. *Distribution Generated Taste-and-Odor Phenomena*. AwwaRF Report, AWWA Bookstore catalog no. 90897. AWWA, Denver.

Taste

- Taste tests can only be run on water known to be safe for drinking
- Usefulness is limited
- Classifications
  - Sweet
  - Sour
  - Bitter
  - Salty

Odors

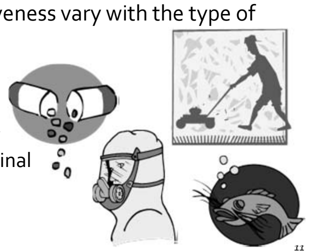
- Human sense of smell is more sensitive than taste, so odor tests are run most commonly in water treatment plants

Odors

- Most frequently caused by algae or decaying organic matter
- Intensity and offensiveness vary with the type of organic matter
- Classifications

  Aromatic
  Grassy
  Septic
  Rotten egg

  Fishy
  Musty
  Medicinal



Significance

- Odor tests can be used to evaluate how well a plant removes taste and odor causing organic materials
- Odor tests can also be used to detect problems in the distribution system
  - Odors in dead-end water mains may have a significant bacteriological buildup
  - Chlorine odor can indicate the loss of free chlorine caused by stagnation, slime buildup, and/or anaerobic conditions

Sampling

- Water samples should be taken from raw and finished waters
- Preferably, use glass containers because plastic may have their own odor
- Mixing of sample should be kept to a minimum until ready for analysis
  - Aeration may reduce odor causing compounds
- Odor tests should be run ASAP – within 24 hours

Common Taste & Odor Complaints

Customer Complaint	Possible Cause
Red water or reddish-brown staining of fixtures and laundry	Corrosion of iron pipes or presence of natural iron in raw water
Bluish stains on fixtures	Corrosion of copper lines
Black water	Sulfide corrosion of copper or iron lines OR precipitations of natural manganese
Foul tastes and/or odors	Byproducts from microbial acitvity
Loss of pressure	Excessive scaling, tubercule (buildup from pitting corrosion), leak in system from pitting or other type of corrosion
Lack of hot water	Buildup of mineral deposits in hot water system (can be reduced by setting thermostats to under 140ºF)
Short service life of household plumbing	Rapid deterioration of pipes from pitting or other types of corrosion

Methods of Determination

Threshold Odor Test

- Measured in Threshold Odor Number (TON)
- Determined by diluting a sample with odor-free water until the least definitely perceptible odor is achieved
- More accurate with more people conducting test

$$TON = \frac{A + B}{A}$$

Where: A = mL sample
B = mL odor-free water

Methods of Determination

Flavor Profile Analysis

- Can be applied for both taste and odor causing compounds
- Panelists are trained in the proper methods of tasting and sniffing samples and are taught to identify and rate the attributes of both tastes and odors
- Standards can be made from sucrose for sweetness, citric acid for sourness, sodium chloride for saltiness, and coffee for bitterness
  - Geranium leaves may also be used for a standard geranium odor in a water sample

Methods of Determination

Quantitative Methods

- How much is present
  - Closed-loop Stripping Analysis
  - Solid Phase Microextraction (SPME) by GC/MS
  - Purge and Trap (dynamic headspace)
- Complaint calls can be received with Geosmin and MIB at 10 ppt (parts per trillion)

Treatment of Taste & Odor

- There are two different areas taste and odor problems can begin
  - Source water
    - can be treated in source water or at the treatment plant
  - Distribution system
    - can be caused by corrosive water leaching metals into water or low chlorine residuals resulting in bacterial growth in water

Treatment

Source Water Treatment

- Early detection of an algal bloom is best
  - Usually have to have historical data to know when blooms occur
  - Data tracking
    - temperature
    - pH
    - turbidity
    - nutrient removal
  - Early detection by
    - underwater visual inspection
    - flavor profile analysis
    - algae collection and identification

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Treatment

Source Water Treatment

- Copper sulfate
  - Operations methods
    - aeration
    - blending treated water with non-treated water
    - selective withdrawal
  - Operational tools
    - alum
    - ferric salts
    - artificial circulation - prevents lake stratification
    - removal of fish - stir up sediments
    - dredging of lake/reservoir (extreme)

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Treatment

Treatment in Plants

- Most plants don't have the luxury of having protected reservoirs they can treat to prevent problems before the come into the plant
- Best way to prevent is to look at historical data
  - e.g. if algal blooms occur when water reaches certain temperature

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Treatment

Treatment in Plants

- Oxidizers
  - Ozone
    - removes 90% of Geosmin and MIB
  - Chlorine dioxide
    - removes phenolic and medicinal odors
  - Potassium permanganate
    - removes grassy and cucumber
- PAC
- Biological filtration

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Distribution System

- Look at historical data
  - What time of year are complaints made
  - Where there are breaks, repairs, or replacements on the water main
  - Was there a possibility of cross-connection and backflow
- Always remember, as temperature increases during the summer, chlorine residual drops
  - Chlorine can mask a taste or odor
  - Bacteria can grow with low/no residual chlorine
  - Either of these problems can cause taste and odor problems

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Distribution System

- Problems
  - Getting a good description from you customer
    - e.g. one person may say the water has a metallic taste and another may say it tastes like sewage
- Getting samples
  - Take at customer's house
  - Make sure customer checks sample to see if taste or odor problem is present in the sample you just collected
    - if not, no need to send to lab

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Distribution System

- Once a problem has been identified, work upstream from the customers tap to find the source of the problem
- Once you have solved a customer's problem, you learn more about your distribution system and you increase customer confidence
- Operational tools
  - Flushing mains
  - Reconfiguring mains
  - Cross-connection control

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Taste and Odor

- Some treatment methods may remove taste and odor problems, by doing so, they may add new taste and odors that are offensive
- For the treated water industry to move forward, more effort is need to:
  - Characterize taste and odors
  - Develop analytical procedures
  - Detect and identify causes of taste and odor problems
  - Develop economical solutions for minimizing taste and odor problems

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Examples of Customer Complaints

Customer Complaint	Possible Cause
Red water or reddish-brown staining of fixtures and laundry	Corrosion of iron pipes or presence of natural iron in raw water
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Loss of Pressure	Excessive scaling, tubercule (buildup from pitting corrosion), leak in system from pitting or other type of corrosion
Lack of hot water	Buildup of mineral deposits in hot water system (can be reduced by setting thermostats to under 140°F [60°C])
Short service life of household plumbing	Rapid deterioration of pipes from pitting or other types of corrosion

Section 16

Preventive Maintenance

PUMP REVIEW

Pump Types

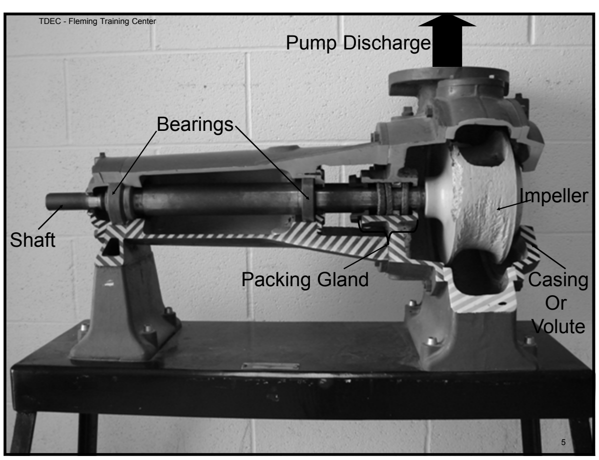
- There are two main types of pumps used in water treatment:
  - Positive Displacement
    - used for small volumes
    - more accurate
    - chemical feeders
  - Centrifugal
    - used for big flows

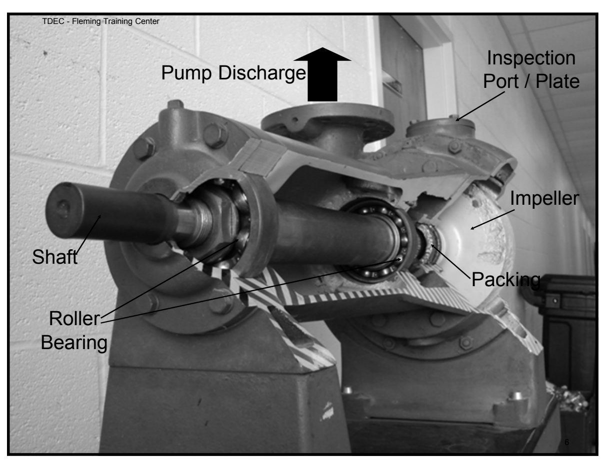
Centrifugal Pumps

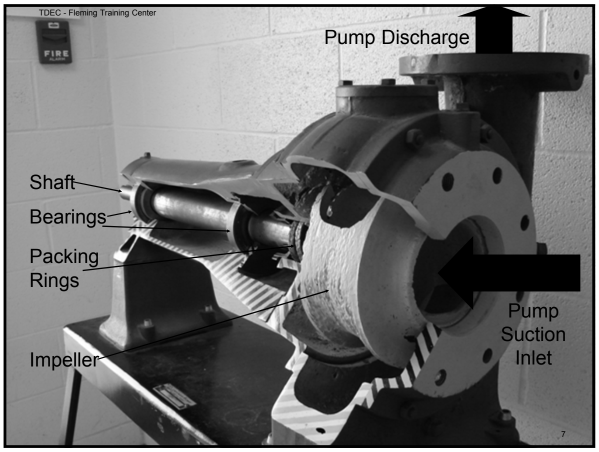
- Centrifugal pumps are velocity type pumps
- Most common type of pump found in water utilities
- Vary in size, shape, and width of impeller
- Vary in a wide range of flows and pressures

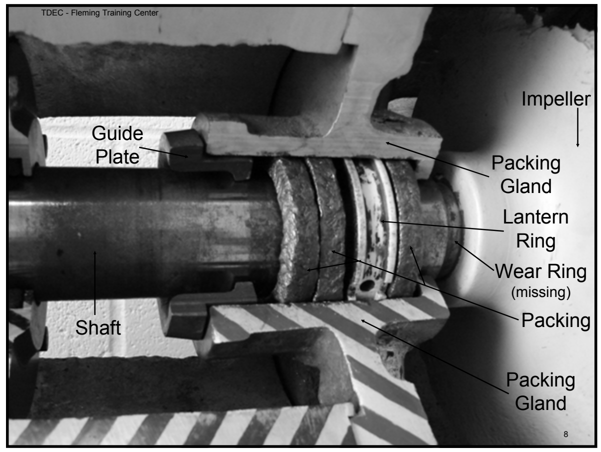
Centrifugal Pumps

- Centrifugal pumps consist of many rotating parts
- Three designs for impellers:
  - Axial
  - Radial
  - Mixed









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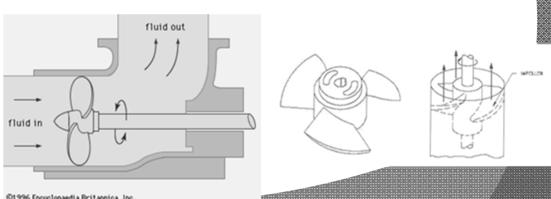
Centrifugal Pumps

Axial Flow Design

- Propeller shaped impeller and ads head by lifting action on vanes



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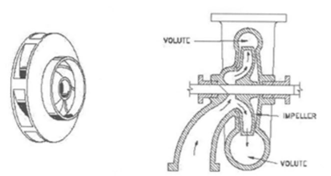
Centrifugal Pumps

Radial Flow Design

- Flow from impeller is thrown outward
- Water enters from eye or center of impeller



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Centrifugal Pumps

Mixed Flow Design

- Impeller has both axial and radial flow design features combined

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Centrifugal Pumps

Mechanical Parts

- Volute
  - The case or housing holding the impeller
  - Usually made of cast iron and spiral shape

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Centrifugal Pumps

Mechanical Parts

- Foot valve
  - A check valve placed in the bottom of the suction pipe which allows water to enter the casing to hold prime

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Centrifugal Pumps

Mechanical Parts

- Bearings
  - Roller bearings support the pump shaft to guide rotation
- Packing
  - rings of graphite materials used to control leakage along the shaft
- Wear rings
  - rings made of brass placed on the impeller to control leakage of water from the sides of the impeller

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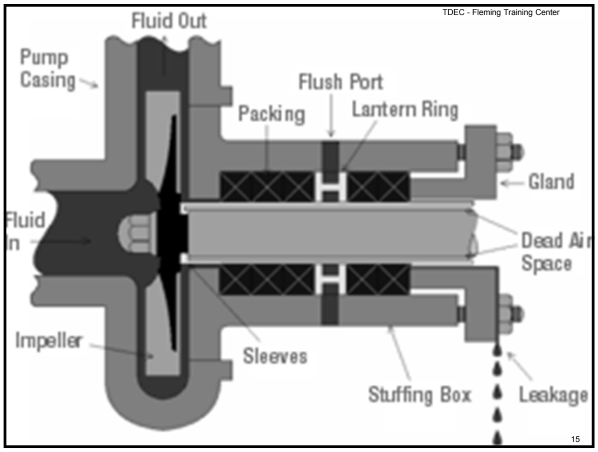

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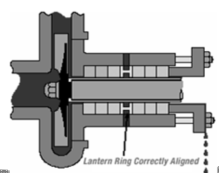
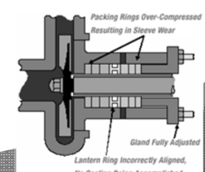
Centrifugal Pumps

Mechanical Parts

- Lantern ring
  - A small perforated ring placed around the shaft to form a liquid seal that lubricates the packing





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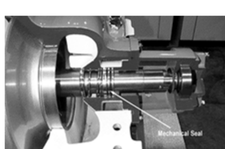
Centrifugal Pumps

Mechanical Parts

- Mechanical seal
  - A seal placed on the pump shaft to prevent leakage along the shaft and leak proof
  - Also prevents air from entering the pump



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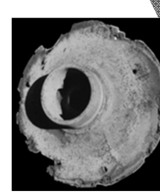
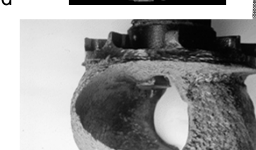
Centrifugal Pumps

Pump Operation

- Cavitation
  - A condition where a partial vacuum forms near the impeller blade and the pump case causing a pinging sound to implode against the impeller
  - Will damage the impeller causing the pitting condition of the metal





This impeller was damaged by cavitation

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Centrifugal Pumps

Pump Conditions

- Water hammer
  - The potential damage occurred from closing water valves to quickly
  - The sudden change in water direction or water velocity creates great water pressure

Preventive and Predictive Maintenance

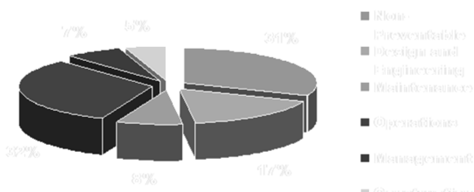
Pump Maintenance

Types of Maintenance

Reactive → Preventive → Condition Based → Proactive

Reactive	Preventive	Condition Based	Proactive
"Fix it when it breaks" • Costly • Risky	Scheduled • Reduced failures • Costly • May cause damage	Determined by an objective measure of need • More effective • Safely eliminates PM • Reduces capital	Preemptive action to optimize reliability, eliminate defects & avoid failure • Most effective • Minimizes failures • Reduces capital

Maintenance Costs



Over 60% of equipment's lifetime maintenance costs were caused by preventable errors during design, procurement, installation, operation and maintenance.

Preventive Maintenance

- Preventive maintenance (P/M) is a schedule of maintenance activities aimed at preventing pump breakdowns and failures
- It is designed to preserve and enhance equipment operations by equipment checks, system overhauls, oil checks and other detailed maintenance checks on equipment

Preventive Maintenance

Long Term Benefits of P/M

- Improved equipment reliability and longevity
- Decrease in cost and replacement of parts
- Decrease in down time of equipment

Preventive Maintenance

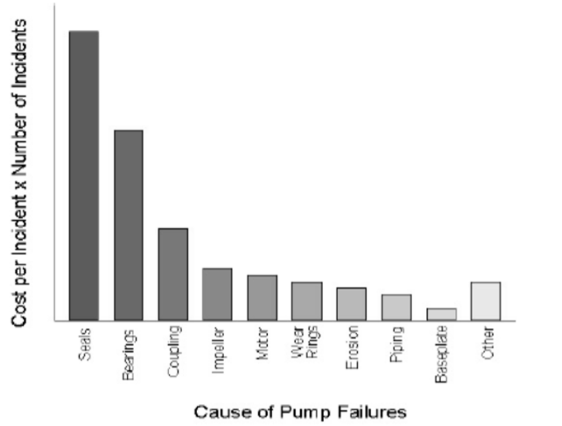
Breakdown Maintenance

- Includes the failure of equipment due to no P/M measures
- Reasons for failures
  - No planning of servicing equipment
  - No preventive measures, checks, service and monitors

Preventive Maintenance

Breakdown Maintenance

- Cost of breakdowns
  - Lost time of the equipment
  - Dollar cost of the part repairs or replacement
  - Customer service



Preventive Maintenance

Breakdown Maintenance

- Avoid the breakdown failure mode
  - Bad operation habits
  - Run to fail
  - No P/M inspections
  - No equipment checks by operators

Goals of Preventive Maintenance

- Define P/M in your plant and establish some set goals of performance of equipment
- Locate equipment needs
  - Look at a workable goal
  - Start with something that can be achieved

Goals of Preventive Maintenance

- Describe and assign P/M functions
  - Activities by operators
  - Activities by maintenance personnel
- Describe the P/M function of equipment
  - Perform P/M or SOP’s
  - Frequency of checks goals:
    - week, month, year

Goals of Preventive Maintenance

- Define the scope of work and define the needs of maintenance or electrical work
- Establish the operations check on equipment operation
- Establish clear work goals
  - Focus on the frequency of equipment checks and historical trends of equipment
- Look at cost savings, increased run times
- Savings on parts and energy

Establish A Preventive Maintenance Program

- Define the inspection check plan on equipment
- Define the frequency of inspection to a weekly or monthly inspection
- Define all the equipment involved or types of pumps, chlorine feeders, chemicals, clarifiers, valves, water tanks, hydrants, meters

Establish A Preventive Maintenance Program

- Locate equipment information on pump labels and tags

Establish A Preventive Maintenance Program

- Locate OEM (Original Equipment Manuals), catalogs and websites
- Locate operations SOP's on equipment
- Establish preventive maintenance SOP on each piece of equipment or pump
- Train personnel, operators and staff on P/M schedules

Establish A Preventive Maintenance Program

- Record all P/M data, records on equipment, and CMMS (Computer Management Maintenance Systems) files
- Create parts inventory listing
- Start a monthly list of P/M work orders to check equipment
- Start a weekly out of service inventory sheet for equipment
  - List causes and date to return to service

Preventive Maintenance Inspections

- Plan and schedule the work orders and seek your data on equipment
- Establish data recording levels of equipment settings
  - i.e. temperature, pressure settings
- Set equipment parameters for data
- Establish parameters for oil measures and temperature and other settings

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Preventive Maintenance Inspections

- Establish run times of equipment
- Decide weekly or monthly check and frequency
- Record data and historic trends of equipment
- After 6 months, establish less breakdowns
- Last phase: trend equipment toward predictive maintenance and consult with vibration analysis, oil analysis and thermal inspection

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Predictive Maintenance

- Predictive maintenance will analyze equipment operations with a proactive predictive analysis of real time data of equipment operation and assessing the measurement technology available on equipment operations

- Not to be done by operator
- Trained professionals are needed

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Predictive Maintenance

- Predictive processes include
  - Vibration analysis
  - Laser alignment
  - Heat thermography
  - Ultrasonic test
  - Oil analysis
- Predictive maintenance uses technology to predict equipment operations and maintenance schedules

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Predictive Processes

- All pump and motors are tested for wear and run times of equipment for bearing wear
  - Laser alignment of pumps and motors for vibration analysis
  - Lubrication wear is tested for mineral deposits of bearing failure

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Predictive Processes

- Down time failures are predicted and avoided
- Equipment conditioning to record on time telemetry of equipment run times and on line monitors
- Cost benefits
  - to improve plant maintenance
  - reduced failures
  - no downtimes
- Predictive processes can save money

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Predictive Processes

Vibration Analysis

- Can identify defects such as
  - Rotor unbalance
  - Coupling misalignment
  - Identify bearing frequency
  - Mechanical looseness
- Looks at frequency and severity of defects along with data trials

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Predictive Processes

Laser Alignment

- The balance of rotating assemblies with laser alignment and shaft balance
- Shaft balance is measured 90^{o} intervals
- A post and return balance of equipment is required along with P/M records of equipment balance and wear indicators

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Predictive Processes

Heat Thermography

- A predictive tool in electrical insulation of wear and damage
- On pumps, thermal indicators can predict
  - Bearing heat and wear as an increase in shaft temperatures
  - Failures or leakages
- More thermal testing of equipment is vital for needed predictive testing and base-lines of pumps and electrical equipment

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Predictive Processes

Heat Thermography

- Heat is one of the greatest of wear indicators of equipment, bearings, and seals
- Heat and temperature sensors on equipment are essential for proper operations
- The use of thermal imaging on equipment is a key factor in location of hot spots on equipment

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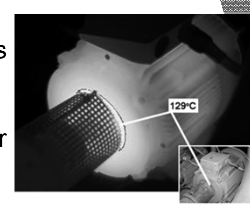
Predictive Processes

Heat Thermography

- Thermography uses a camera which produces an image of temperature variations on equipment with color intensity
  - Hot spots glow in yellow and red colors



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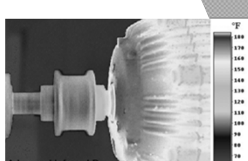
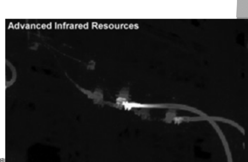
Predictive Processes

Heat Thermography

- Used to locate:
  - Loose electrical connections
  - Friable electrical insulation on wiring
  - Hot spots on electrical panels
  - Worn equipment and circuits





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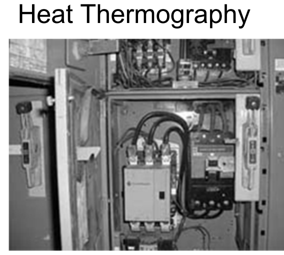
Predictive Processes

Heat Thermography



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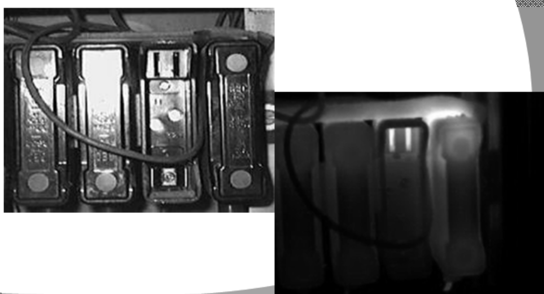
Predictive Processes

Heat Thermography



Predictive Processes

Shock Pulse and Ultrasonic Testing

- Continues to test the vibration frequency pattern of roller bearings
- Establishes a base line of shaft operation to base a defective bearing against

Predictive Processes

Ultrasonic Testing

- Can register audible sounds on headphones such as lifters on cams or valve actions and closings

Predictive Processes

Oil Analysis

- Establish a need for an oil analysis of plant motors and pumps
- Locate current lubrication needs and types of oils and grease
- Schedule of lubrication
  - inspect weekly or monthly

Predictive Processes

Oil Analysis

- What kinds of wear indicators are showing
- Inspect for contamination and used oil indicators
- Oil consumption is an indicator of seal failures

Predictive Processes

Oil Analysis

- Lubrication system rating of extended oil life
- Oil viscosity and rating
- Quality of oils and grease or the cheapest grades
- Chemical oil testing of breakdowns due to heat, metals, sulfurs, or moisture
- Oil filters include better filtration of impurities and clean equipment
- Keep records of oil schedules and results

Predictive Processes

Oil Analysis

- Establish the need for adequate lubrication of equipment
- Lubrication of equipment covers the selection of lubricants related to oil, grease, filters, rating viscosity, oil analysis and the handling or storage of oils

Predictive Processes

Lubricants

- Oil selection is based on OEM (Original Equipment Manuals)
- Lube schedules and frequency established along with system checks
- Analysis of oils can use data of wear times and breakdown of oils and factors

Predictive Processes

Oil Breakdowns

- Lubricants can be the cause of equipment failures
  - Equipment or bearing wear due to fatigue
  - Oil breakdown can be due to excessive heat on equipment
  - Water or moisture leakage
  - Contaminants in the oil such as dust or metals

Predictive Processes

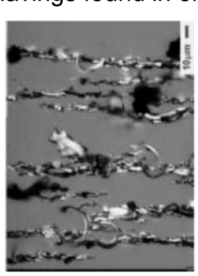
Oil Testing

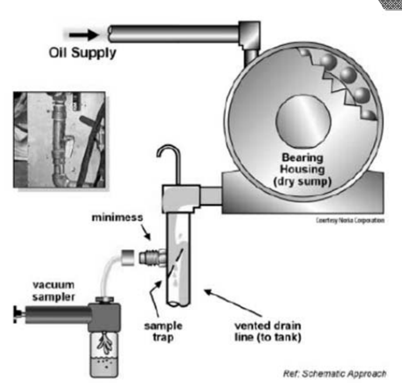
- Oil inspection and proper sampling of equipment is needed
- Lab testing of oils inspect for
  - Water
  - Dust
  - Metal content
  - Viscosity
  - Other contaminants and wear factors
- Oil temperature is key to life of oil usage

Predictive Processes

Oil Testing

Metal shavings found in oil testing





Predictive Processes

Oil Longevity

- Wear indicators of oil require inspecting all equipment for moisture, leaks, leaking oil seals and filter replacements
- Several P/M maintenance checks can locate oil leaks of pumps, seals and other maintenance records

Predictive Processes

Oil Schedules

- Plan oil schedules and lube records
- Plan all oil checks and changes
- Use index cards on oiling schedules
- Use data cards and sheets for each pump
- Indicate oil locations and types of oils used

Predictive Processes

Oil Schedules - Recycle

- A good environmental response is to always recycle spent oils
- Have a plan with a local recycler and vendor

RECYCLE USED OIL

Predictive Processes

Oil Schedule - Recycle

- Have a spill protection plan
- Store all used oils to be recycled
- Used berms and soil dry
- <u>Always</u> recycle oil

Predictive Processes

Oil Schedule - Recycle

- Never pollute water ways or land areas

Predictive Processes

Cost Savings

- Providing results and proof of cost savings of predictive maintenance
- Less down time of equipment
- Operations of equipment are improved and less failures

Predictive Processes

Computer Maintenance Management System (CMMS)

- CMMS is a computer driven maintenance management system of planned and work order driven maintenance reports and inspections

Predictive Processes

CMMS

- Predicts time schedules and trend work maintenance of equipment
- Able to keep cost work times, parts and overtime
- Can keep parts inventory of all equipment
- Provide monthly summary reports of cost and work
- Can contract out work service contracts

Predictive Processes

CMMS

- Will generate a planned maintenance schedule of equipment services and work orders of scheduled work
- Will generate planned work schedules and inventory of work orders and data

Predictive Processes

CMMS

- Produces cost summary and work time generation for maintenance cost and projections for failures
- Keeps inventory of parts and service contracts and complete inventory of tools and equipment
- Tracks chemical cost and usage

End Results

- Complete process improvement of P/M
- Improved operations; less downtime
- Less equipment failures and reduced cost
- Conditioned equipment for complete life cycle
- A complete road map for plant maintenance
- Start with training plant operators toward preventive maintenance

Lasting Thoughts

- Plant maintenance has to be planned to operate and service equipment. Preventive measures have to be provided in timely schedules to prevent equipment failures.
- A planned preventative and predictive maintenance program will save you money and downtime of equipment and make plant operations more efficient.