Introduction to Water Treatment

For All Grades

Course # 301

Week 2

Updated 11-2023

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Section 1

Water Stability

Stabilization

Corrosion and Scaling Control

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Objectives

- Purpose of Stabilization
- Corrosion
- Scale Formation
- Control Methods
- Determining Stability

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Purpose of Stabilization

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Purpose of Stabilization

- 1.) To protect public health
  - Corrosive water can leach toxic metals from distribution piping and household plumbing
    - lead and copper
  - Corrosion of cast-iron mains causes tubercules (iron deposits) that can protect bacteria from chlorine, allowing them to grow and thrive

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Purpose of Stabilization

- 2.) To improve water quality
  - Corrosive water attacking metal pipes can cause color, taste & odor problems
  - Red water from cast-iron mains
    - the iron will stain customers' plumbing fixtures and laundry and make the water's appearance unappealing for drinking and bathing
  - Corrosion of copper pipes can cause metallic taste and blue-green stains on plumbing fixtures and laundry

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Purpose of Stabilization

- 3.) To extend the life of plumbing equipment
  - Aggressive water reduces the life of valves, unprotected metal, asbestos-cement pipe, plumbing fixtures, water heaters
  - Buildup of scale and corrosion products reduces capacity of pipes, which reduces distribution system efficiency and increases pumping costs
  - If scale deposits go unchecked, pipes can become completely plugged

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Purpose of Stabilization

- 4.) To meet federal and state regulations
  - Lead and Copper Rule - 1991
  - Systems must check if their water is corrosive enough to cause lead and copper to be present
  - Samples taken at high-risk locations
    - homes with lead pipes, lead service lines or lead solder

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Lead and Copper Rule

- Samples are to be collected after water has sat in lines for at least 6 hours - first draw
- 1 liter take from cold water tap in kitchen or bathroom
- Action levels
  - Lead is 0.015 mg/L
  - Copper is 1.3 mg/L
- If a system exceeds action level in more than 10% of samples, steps must be taken to control corrosion

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Stabilization

- The process for controlling corrosion and scale deposits on pipelines and plumbing fixtures
- Corrosion and scale deposits in the distribution system can be very costly for utility
  - Problems range from excessive customer complaints to increased pumping costs, to replacement of mains due to leaks and breaks
  - Corrosion control is also important in protecting consumers from the dangers of excess lead and copper

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Stability

Scale-Forming ← Stable Water → Corrosive Water

- Water is considered stable when it is just saturated with calcium carbonate
- It will neither deposit nor dissolve calcium carbonate

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Corrosion

Definition of Corrosion
Factors Affecting Corrosion
Types of Corrosion

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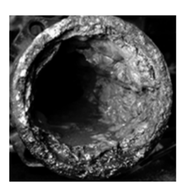
Corrosion

- The gradual deterioration or destruction of a substance or material by chemical reaction with the water
- Water that promotes corrosion is called *corrosive* or *aggressive water*



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Factors Affecting Corrosion

- Dissolved Oxygen
  - as dissolved oxygen increases, the rate of corrosion increases
- Total Dissolved Solids
  - increases electrical conductivity of water
- Alkalinity
  - buffers a change in pH - decreases corrosion
- pH
  - low pH promotes corrosion
  - high pH can be scale-forming

Factors Affecting Corrosion

- Hardness
  - a small amount can form a protective layer of scale on pipes to prevent corrosion
- Temperature
  - corrosion occurs faster in warmer water
- Flow Velocity
  - increased velocity can increase rate of corrosion
  - decreased velocity can increase rate of corrosion **if** water is aggressive

Factors Affecting Corrosion

- Type of Water
  - galvanic corrosion is corrosion of dissimilar metals
- Electrical Current
  - improperly grounded household electrical systems can accelerate corrosion
- Sulfate Reducing Bacteria
  - H_2S gas released - causes rotten egg odor
  - can react with water to form H_2SO_4 which is highly corrosive
  - produces black sulfide deposits

Factors Affecting Corrosion

- Iron Bacteria (Gallionella)
  - Converts dissolved iron into precipitate causing red-water complaints
  - Produces slime which protects against chlorine and prevents accumulation of $CaCO_3$
  - Bacteria can slough off causing taste and odor
  - Bacteria can change pH and alkalinity of water as they give off gases, mainly CO_2

Types of Corrosion

- Localized
  - Most common, most serious
  - Attacks surface unevenly, leads to rapid failure of metal
  - Two types:
    - galvanic - caused by the connection of dissimilar metals in an electrolyte such as water
    - concentration cell - forms deep pits or tubercules
- Uniform
  - Occurs evenly over all surface
  - Due to low pH and alkalinity

Localized Corrosion

Localized Corrosion

Sink hole caused
by 8-in main break

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Galvanic Corrosion

Corroded End (anode)	Most Active
Magnesium	+
Magnesium alloys	↑
Zinc	
Aluminum	
Mild Steel	
Wrought (black) Iron	
Cast Iron	Corrosion Potential
Lead-tin Solders	
Lead	
Tin	
Brass	
Copper	↓
Stainless Steel	−
Protected End (cathode)	**Least Active**

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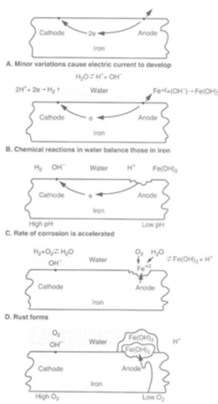
Galvanic Corrosion



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Scale Formation

Definition of Scale Formation
Factors Affecting Scale Formation
Types of Scale Formation

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Scale Formation

- The precipitation of certain hardness-causing ions with other minerals to form a coating on pipe walls
- The formation of a small amount of scale can help protect the pipe from corrosion
- Uncontrolled deposits reduce the carrying capacity of the pipe
- Can also decrease the efficiency of boilers, water heaters, etc

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Scale-Forming Compounds

- $CaCO_3$ - calcium carbonate
- $MgCO_3$ - magnesium carbonate
- $CaSO_4$ - calcium sulfate
- $MgCl_2$ - magnesium chloride

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Scale Formation

- Scale is formed when magnesium and calcium combine with other minerals dissolved in the water
  - Ca and Mg are then precipitated out coat the pipe walls
- Saturation Point - the point at which a solution can no longer dissolve any more of a particular chemical
  - Precipitation will occur past this point

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Scale Formation

- Solubility varies with temp, pH, TDS, etc
- The saturation point of $CaCO_3$ depends primarily on the water's pH
  - As pH increases, scale formation increases
- Solubility of $CaCO_3$ in water decreases as temp increases
  - The higher temps in water heaters causes $CaCO_3$ to precipitate out and build up on pipes, tank walls, and heating elements

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Control Methods

pH and Alkalinity Adjustment
Protective Coatings
Corrosion Inhibitors

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Control Methods

- 1.) pH and alkalinity adjustment
- 2.) Formation of $CaCO_3$ coating
- 3.) Use of corrosion inhibitors and sequestering agents

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pH and Alkalinity Adjustment

- Soft waters with pH less than 7 and poorly buffered (low alkalinity) will be corrosive to lead and copper
- Water with too much alkalinity can also be corrosive
- A moderate increase in pH and alkalinity can reduce corrosion
- A moderate decrease in pH and alkalinity can prevent scale formation

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pH and Alkalinity Adjustment

- Lime is most commonly used
  - Lime alone or in combination with other chemicals forms a scale on the pipe that protects the pipe from corrosion
    - too much reduces capacity
  - Less expensive than other chemicals
  - Works well
  - Removes CO_2 from water

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pH and Alkalinity Adjustment

- Slaked lime (*hydrated*) - $Ca(OH)_2$
  - For small plants, more cost effective
  - Powder
  - In bags or bulk
  - Should be kept dry and well ventilated
    - moisture will start the slaking process
  - Dry feeder
    - water added, forms slurry

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pH and Alkalinity Adjustment

- Unslaked lime (*quicklime*) - CaO
  - For plants using a lot of lime
  - Powder to pebble size
  - Usually handled in bulk
  - Should be kept dry and well ventilated
  - Dry feeder
    - adds lime to a slaker where water is added to form a slurry

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pH and Alkalinity Adjustment

- Note:
  - Quicklime and alum should never be stored together
  - When mixed, a large amount of heat is given off
    - Hydrogen gas can be released

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pH and Alkalinity Adjustment

- Sodium carbonate (*soda ash*) - Na_2CO_3
  - White, alkaline powder or granules
  - Available in 100 lb bags or bulk
  - Store in dry, well ventilated area away from acids
  - Can be added along with lime to increase alkalinity
  - Hopper must have agitator
  - Dry feeder
    - does not dissolve quickly
    - requires larger solution tank and longer mixing time

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pH and Alkalinity Adjustment

- Sodium bicarbonate (*baking powder*)- $NaHCO_3$
  - White, alkaline powder or granules
  - Available in 100 lb bags or barrels up to 400 lbs
  - Store in cool, dry, well ventilated area away from acids
  - Solutions are caustic
  - Dry feeder
    - must have caustic-resistant lines, solutions, pumps, etc

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pH and Alkalinity Adjustment

- Sodium hydroxide (*caustic soda*) - NaOH
  - Liquid or dry form
    - both highly caustic
  - Liquid form must be kept warm to prevent crystallization
  - Increases pH more than other chemicals
  - Requires special feed lines, tanks
  - Dry form dissolves immediately
  - Addition of water produces tremendous amounts of heat
  - Metering pumps must be designed for caustic solutions
    - valves fittings must be caustic-resistant, such as PVC

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pH and Alkalinity Adjustment

- Sulfuric acid - H_2SO_4
  - Corrosive, dense, oily liquid
  - Available in 55-gallon drums and tank trucks
  - Must add acid to water
  - Metering pumps must be corrosion-resistant
  - Diluted acid is more corrosive than pure acid

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Use of Coatings

- A protective coating on pipe surfaces can inhibit corrosion
  - Lime, alone or in combination with soda ash or sodium bicarbonate, can be added to precipitate a $CaCO_3$ scale on the pipe walls
  - A coating of cement, epoxy, etc can be applied to interior pipe surfaces
  - Polyphosphates and sodium silicate can be used for corrosion control and stabilization

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Polyphosphates

- Work as <u>sequestering agents</u>
  - Tie up Fe and Mn to prevent color and taste complaints
- They also tie up calcium carbonate to prevent excess scale
- Calcium (from alkalinity) is required as a catalyst
- If low alkalinity, need a blend of polyphosphates and orthophosphates
- Orthophosphates coat pipes; polyphosphates sequester
- Orthophosphates work well for lead and copper protection

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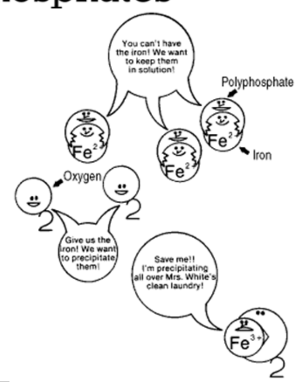
Polyphosphates



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Phosphates

- Sodium hexametaphosphate
- Zinc orthophosphate
- Sodium zinc phosphate
- Available in solid or liquid form
- Can be fed from shipping container

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Sodium Silicate (Na_2SiO_3)

- Combines with calcium to form a hard, dense coating on interior of pipe
- Works well in waters with low hardness & alkalinity and relatively high flow velocities
- Must be approved by NSF (National Sanitation Foundation)
- Thick, opaque alkaline liquid
- Available in barrels and bulk
- Non-corrosive
- *Can be referred to as "water glass"*

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Corrosion Inhibitor Safety

- Protective clothing, equipment must be worn
- Proper storage
  - keep dry chemicals dry
  - store caustic liquids in proper container
- Clean up spills immediately
- Have a shower and eye wash available

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Determining Stability

Langelier Saturation Index
Marble Test
Coupon Test

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Stabilization Tests

- Langelier Saturation Index (LSI)
- Marble Test (CCPP)
  - Calcium carbonate precipitation potential
- Coupon Test
  - Aka nail in a filter

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Langelier Saturation Index

- Used to indicate how close the water is to the equilibrium point
- LSI= pH - pH_S
  - pH = actual pH of water
  - pH_S = determined by calcium carbonate saturation point
    - pH_S = A + B - log (Ca^{2+}) - log (alkalinity)
      - A = determined from temperature
      - B = determined from TDS

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Langelier Saturation Index

- If the LSI is **zero**, the water is **stable**
- If the LSI is **positive**, the water will be **scale-forming**
- If the LSI is **negative**, the water will be **corrosive**

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Corrosivity Characteristics as Addressed by Indices

Corrosive Characteristics	Langelier Saturation Index (LSI)	Aggressive Index
Highly Aggressive	< -2.0	< 10.0
Moderately Aggressive	-2.0 to 0.0	10.0 to 12.0
Non-aggressive	> 0.0	> 12.0

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Marble Test

- Also called Calcium Carbonate Precipitation Potential (CCPP)
- Used to determine the degree to which a sample of water is saturated with calcium carbonate
  - Over-saturated, under-saturated, just-saturated
- Water in intimate contact with powdered calcium carbonate (calcite) will approach saturation

CCPP, mg/L = initial hardness, mg/L – final hardness, mg/L

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Marble Test Procedure

- Measure the temperature pH, hardness, and, if desired, the alkalinity of the sample being tested
- Add approximately one (1) gram of calcium carbonate and stir for 5 minutes at a rate high enough to keep the calcium carbonate in suspension and the sample vigorously agitated
- Filter the remaining sample in lab
- Determine the hardness and the final alkalinity on the filtrate (water that has passed through the filter)

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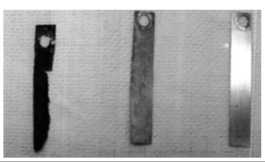
Coupon Testing

- Measures the effects of the water on a small section of metal (the coupon) inserted in a water line
- After a minimum of 120 days, the inserts are removed, cleaned, weighed and examined
- The weight loss or gain of the coupon can provide an indication of the corrosion or scaling rate



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Determining Stability

- In the distribution system
  - Evaluate effects of corrosion and scaling
  - Records of main breaks and leaks due to corrosion
  - Info on how well older valves operate
    - if difficult to operate, may be coated with scale
  - Info on reduced flow rates in mains
    - build up of scale
  - When possible, pieces or sections of pipe removed should be tagged and evaluated

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Determining Stability

- In customer's plumbing
  - Customer complaints
    - Red water, brown water, loss of pressure
    - Location of where problems occur
    - Time of year
- For meeting regulation requirements
  - Lead and Copper Rule (LCR)
    - Must take steps to reduce corrosion if action levels are exceeded

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Stability

- Water Quality Data
  - Determine if there is an increase in metals in the distribution system
    - i.e. copper, zinc, cadmium
  - Before initiating a corrosion control program, check with others in the field who can give sound advice
  - Using the wrong stabilization method can increase problems

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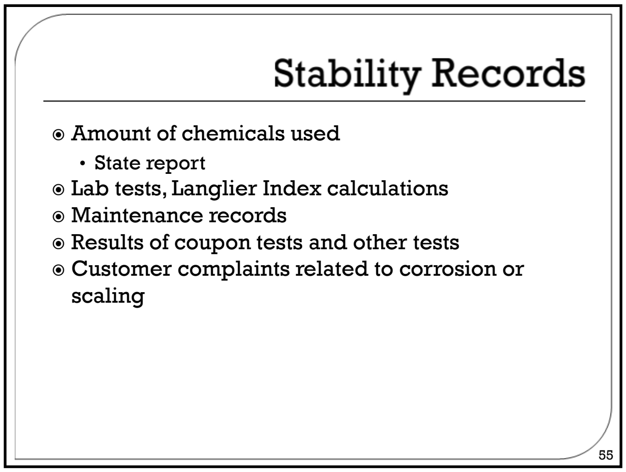
Stability Records
Amount of chemicals used
State report
Lab tests, Langlier Index calculations
Maintenance records
Results of coupon tests and other tests
Customer complaints related to corrosion or scaling
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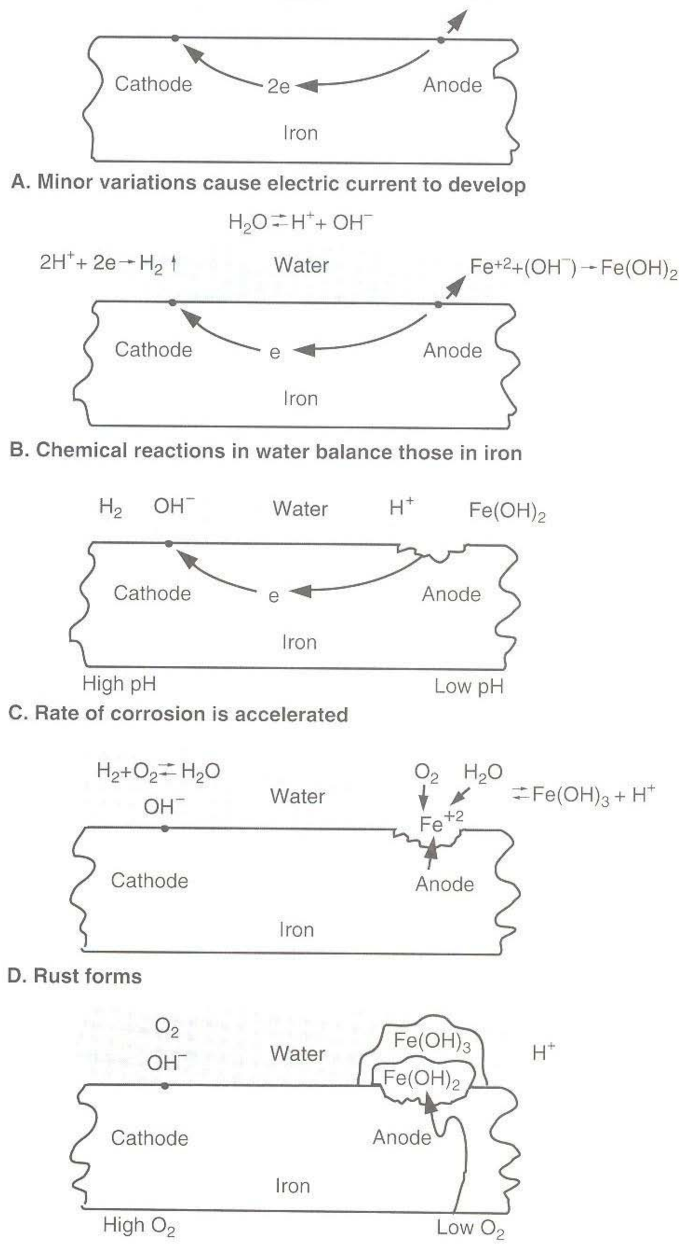
Stabilization Vocabulary

______1. Aggressive
______2. Anode
______3. Cathode
______4. Concentration Cell Corrosion
______5. Corrosion
______6. Corrosive
______7. Coupon Test
______8. Galvanic Corrosion
______9. Galvanic Series
______10. Iron Bacteria
______11. Langelier Index
______12. Localized Corrosion
______13. Milk of Lime
______14. Red Water
______15. Saturation Point
______16. Sequestering Agent
______17. Slaker
______18. Stabilization
______19. Tubercules
______20. Uniform Corrosion
______21. Unstable

A. A chemical compound such as EDTA or certain polymers chemically tie up other compounds or ions so they can't be involved in chemical reactions.
B. To deteriorate material, such as pipe, through electrochemical processes.
C. Bacteria that use dissolved iron as an energy source.
D. The lime slurry formed when water is mixed with calcium hydroxide.
E. Knobs of rust formed on the interior of cast iron pipes due to corrosion.
F. Corrosive.
G. A term used to describe rust-colored water due to the formation of ferric hydroxide from iron naturally dissolved in the water or as a result of the action of iron bacteria.
H. A listing of metals and alloys according to their corrosion potential.
I. To be corrosive or scale-forming.
J. Positive end (pole) of an electrolytic system.
K. The point at which a solution can dissolve no more of a particular material.
L. A numerical index that indicates whether calcium carbonate will be deposited or dissolved in a distribution system.
M. The water treatment process intended to reduce the corrosive or scale-forming tendencies of water.
N. Negative end (pole) of an electrolytic system.
O. A form of localized corrosion that can form deep pits or tubercules.
P. A form of corrosion that attacks a small area.
Q. The part of the quicklime feeder that mixes the quicklime with water to form hydrated lime.
R. A form of localized corrosion caused by the connection of dissimilar metals in an electrolyte such as water.
S. The gradual deterioration or destruction of a substance or material by chemical reaction. The action proceeds inward from the surface.
T. A form of corrosion that attacks material at the same rate over the entire area of its surface.
U. A method of determining the rate of corrosion or scale formation by placing metal strips of a known weight in the pipe.

Answers to Stabilization Vocabulary

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



Section 2

Iron & Manganese

Iron and Manganese Control

CSUS Water Treatment Volume 2

Iron and Manganese

- Symbol for iron is **Fe**
- Symbol for manganese is **Mn**
- The soluble form is Mn^{+2} and Fe^{+2} (divalent)
- The insoluble form is Mn^{+3} and Fe^{+3} (oxidized)
- The soluble form is converted to insoluble form by a chemical process called oxidation

Iron and Manganese

- No adverse health effects
- Essential to growth of many plants and animals
  - In drinking water, there is no nutrient value for humans
- Low dissolved concentrations in water containing dissolved oxygen (DO)
  - Soluble forms are oxidized to insoluble forms
- Surface water is generally free from iron and manganese
  - Exception is manganese may be found in shallow reservoirs
- Most frequently found in in well and spring systems
  - Bacteria convert insoluble form to soluble causing high iron concentrations in the ground water

Iron and Manganese

- Presence in drinking water is objectionable
  - Will stain laundry, plumbing fixtures, bathtubs and sinks
- Promote growth of bacteria that obtain energy from chemical reaction between iron, manganese, and dissolved oxygen
  - Iron bacteria – Gallionella
  - Form thick slimes on walls of water mains
    - Rust colored from iron
    - Black from manganese
  - Variations in flow will cause slimes to slough off causing taste and odor issues as well as customer complaints

Iron Bacteria

- Oxidizes ferrous ions to form organic slimes
- Bacteria infestation can form from only one cell of iron bacteria
- Found nearly everywhere
  - Anywhere iron and dissolved oxygen are present
- Growth is controlled by chlorination
  - However, the oxidant creates precipitates that will form coating on pipe walls
  - Cause customer complaints when variations in flow

Iron and Manganese

- Detected by observing color of filter bay walls if raw water is chlorinated
  - Black stains below water level indicate high levels of manganese
  - Brownish-black stains indicate presence of both iron and manganese
- sMCL
  - Iron – 0.3 mg/L
  - Manganese – 0.05 mg/L
    - If concentrations exceed 0.02 mg/L, a distribution system flushing program should be initiated

Measuring Iron and Manganese

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Sample Collection and Analysis

- Results are wrong more often than right due to difficulties in sample collection
  - Opening sampling tap causes the loosely attached scales on pipe walls and sample lines to be dislodged and enter sample bottle
- Sample must be acidified to prevent scale formation on walls of sample bottle
  - Acidify – add nitric acid to drop the pH to less than 2
    - Sample preservation method

Sample Collection and Analysis

- Collect samples from plastic sample line as close to source as possible
- Open tap slowly to suitable rate for sample collection
- Allow sample to run 1 minute for each 10 ft of sample line
- Test samples within 48 hours (holding time) unless acidified
  - Do not acidify if rust or clay particles can be seen in sample
- Preferred method of testing is atomic absorption
- Sufficient accuracy has been obtained with colorimetric methods that use a spectrophotometer

Treated Water Monitoring

- Monitor product water closely when treating for iron and manganese by aeration or chemical addition
  - Laboratory analysis
  - Dose a sample of treated water with chlorine
    - If brown or rust colored floc appears, treatment in inadequate
      - Increase chemical dosage or reduce flows
  - If feeding permanganate and a pink color appears
    - Decrease chemical dosage until pink is no longer visible

Remedial Action

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Alternate Source

- Investigation of alternative sources should include
  - Samples from nearby private wells
  - Discussions with well drillers in the area
  - Discussions with engineers in the state agency
- If well water contains DO, indicates more than one aquifer is being accessed
  - Fe and Mn are typically in deeper aquifers, so those can be sealed off

Phosphate Treatment

- Effective control of iron and manganese if water contains
  - less than 0.3 mg/L manganese
  - Less than 0.1 mg/L iron
- Polyphosphates delay the precipitation for a few days to reduce scale build up on pipe walls
  - Pyrophosphate
  - Tripolyphosphate
  - Metaphosphate
- Polyphosphates should be fed prior to any oxidizing agent (i.e. chlorine, oxygen)
  - Satisfactory results can be obtained by feeding them together

Removal by Ion Exchange

- Ion exchange units similar to downflow pressure filters
  - Water enters through inlet distributor at top of tank
  - Water forced through ion exchange resin into an underdrain
  - Treated water flows to next step in the process
- May be used if water contains no dissolved oxygen
  - DO will oxidize soluble to insoluble precipitate that will foul the resin
- Monitor treated water on daily basis
- When iron and manganese start to appear in treated water, the unit must be regenerated
  - Regenerate with a brine solution mixed with sodium bisulfite

Oxidation by Aeration

- Aeration oxidizes iron to form insoluble ferric hydroxide
  - Then removed by sedimentation and/or filtration
- Aeration either bubbles air through water or scatters water into the air
  - Air-into-water
    - Diffusers produce many small bubbles in water
  - Water-into-air (slime growth must be controlled)
    - Forced draft
    - Multiple trays
    - Cascades
    - Sprays

Oxidation by Aeration

- Removes carbon dioxide (CO_2) which will raise the pH
  - Higher pH leads to shorter time required for oxidation
- Flow must be carefully controlled
  - Too high flow will not allow enough time for reactions to occur
- Reaction basin follows aeration process
  - Allows time for the oxidation reactions to take place
  - Should be baffled to prevent short-circuiting & solids deposition
  - Must have protection against backflow
- Precipitate ferric hydroxide is removed by sedimentation and/or filtration

Oxidation by Aeration

- Major advantage
  - No chemicals required
- Major disadvantage
  - Small changes in raw water quality may affect the oxidation rates and reduce plant production
- Minimum recommended detention time
  - 20 minutes with desirable times of 30-60 minutes
- Lower oxidations rates can be caused by
  - Increased organic substances
  - Decreased pH
  - Reduced temperatures
- Waters with high levels of manganese should not use aeration due to slow oxidation rates

Oxidation with Chlorine

- Oxidizes iron and manganese into insoluble form
  - Manganese dioxide
  - Ferric hydroxide
- Higher chlorine residual means faster reaction times
- Do not use high doses of chlorine in waters that contains high levels of organic color
- Water is dechlorinated through reducing agents
  - Sulfur dioxide (SO_2)
  - Sodium bisulfite ($NaHSO_3$)
  - Sodium sulfite (Na_2SO_3)
- Reaction basin installed between chlorination and dechlorination processes

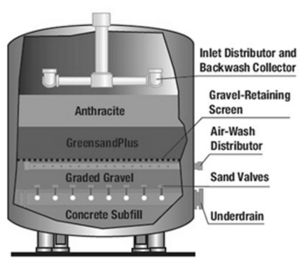
Oxidation with Permanganate

- Oxidizes iron and manganese similar to chlorine
- Dose of permanganate must be exact
  - Too small will not oxidize all the manganese
  - Too large will produce pink water
  - Observation of water will tell you if adjustments are needed
- Conventional filtration can remove precipitated iron and manganese if concentrations are less than 1.0 mg/L
- Manganese greensand is a granular material that is treated with potassium permanganate
  - Can oxidize both iron and manganese
  - Acts as a filter and must be backwashed

Oxidation with Permanganate

- Manganese Greensand Filter
  - Layers of graded gravel, manganese greensand, & anthracite coal
  - Mode of operation depends on Fe and Mn concentrations
    - Continuous regeneration (CR)
      - Up to 15 mg/L iron
    - Intermittent regeneration (IR)
      - Suitable for water with only or mostly manganese and little iron
    - Catalytic regeneration
      - Well water will low concentrations of iron and manganese with pH > 7
  - As water passes through greensand bed two things occur
    - Insoluble iron oxide particles are filtered out
    - Any remaining permanganate is reduced to manganese oxide

Manganese Greensand Filter

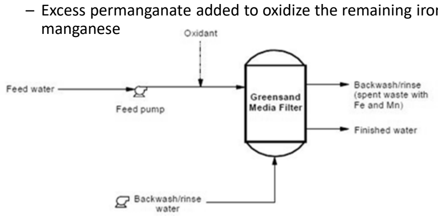


Oxidation with Permanganate

- Manganese Greensand Filters
  - Intermittent Regeneration (IR)
    - Oxidation of manganese occurs directly on greensand
    - Iron will quickly foul out media
    - Head loss will indicate need for backwash and regeneration
  - Catalytic Regeneration
    - Chlorine is added ahead of filter to maintain chlorine residual in bed
      - Keeps greensand continuously regenerated
    - Longer run times and higher filtration rates than other methods

Oxidation with Permanganate

- Manganese Greensand Filters
  - Continuous Regeneration
    - Chlorine and permanganate are added to raw water ahead of greensand bed
      - Chlorine oxidizes iron and any sulfide
      - Excess permanganate added to oxidize the remaining iron and manganese



Oxidation with Permanganate

- Manganese Greensand Filters (Continuous Regeneration)
  - Can remove 95% of iron and manganese
  - Efficiency will decrease as insoluble oxides precipitate accumulate
  - Oxidation potential decreases as pH increases
    - Recommended pH = 6.2
  - Process
    - pH adjustment
    - Chlorine injection
    - Coagulation and flocculation for 10 minutes
    - Potassium permanganate injection
  - Sufficient detention time must allow for chemical reactions to occur

Oxidation with Permanganate

- Manganese Greensand Filters (Continuous Regeneration)
  - Filter influent will have slight pink color
  - Pink will disappear as permanganate is reduced to manganese oxides
  - Manganese oxides precipitate on greensand thus continuously regenerating media
  - Do not underfeed permanganate for extended periods of time
  - Insoluble precipitates will accumulate on filter media during run time
    - Backwashing is required (similar to conventional filters)
    - No need to regenerate media after backwash
    - Air washing can be used to eliminate sticky precipitates on media

Oxidation with Permanganate

- Manganese Greensand Filters (Continuous Regeneration)
  - If charge is lost due to underdosing, media must be regenerated
    - Shut down process and pour saturated solution of 5% $KMnO_4$ into filter; let sit for 24 hours; backwash filter
    - Increase $KMnO_4$ dosage until pink water flows out of greensand media; decrease dosage until slightly pink color before filter
      - Do not decrease dosage too much and cause charge to be lost
  - Pink color is best indication that the greensand is regenerated or recharged

Operating Filters

- Oxidation of iron and manganese is followed by filtration to remove insoluble material
- Perform monthly tests on filter influent to ensure iron is in ferric (Fe^{3+}) state
  - If ferrous iron is still present, oxidation is not complete and chemical addition may be required
- Filters backwashed according to head loss

Troubleshooting

- **Trouble:**
  - filter effluent clear, iron low, manganese higher than raw water
- **Cause:**
  - manganese being leached from greensand grains
  - bed is insufficiently regenerated
- **Solution:**
  - increase frequency of regeneration
  - regenerate bed with sufficient $KMnO_4$ so heavy purple color comes through bed
  - make sure proper influent chemicals are being continuously fed

Troubleshooting

Trouble	Cause	Solution
Filter effluent too turbid with yellow to brownish color. Iron and manganese high.	Too much alkali being fed.	Reduce alkali feed. Maintain correct pH prior to filter (6.2-6.5).
	Polyphosphate being feed ahead of filter.	Discontinue polyphosphate feed.
	Channeling through filters.	Check bed surface for pounds, pockets, and channeling. Backwash and air-scrub if possible.
	Iron is organically bound: reactions with oxidizing agent produce a nonfilterable colloid.	Feed alum or other coagulation prior to filtration.

Troubleshooting

Trouble	Cause	Solution
Excessive pressure drop across bed immediately after backwashing.	Accumulation of greensand fines at surface of bed.	Remove fines by scraping after backwashing; bed replacement may be required. Check head loss is not greater than 10 psi.
	Backwash rate too low.	Increase backwash rate
	Filter bed cemented.	Break up cemented areas with air-water wash combination; bed replacement may be necessary.
	Well through fine sand, silt and colloidal clay.	Check well supply, especially after start up; allow well to pump overboard at start up.

Troubleshooting

Trouble	Cause	Solution
On multiple unit installations, water quality good on some units, bad on others.	Unequal distribution of prefeed chemicals.	Inject chemical at a point where thorough mixing of chemical with raw water occurs before diversion to the various filters.
In CR systems, iron breakthrough before recommended headloss is reached.	Some iron waters filter in depth and do not build up head loss.	Backwash should be initiated by number of gallons instead of by head loss.
In CR systems, faint pink color infilter effluent.	Permanganate feed rate is too high.	Operate filter for 1-2 hours with $KMnO_4$ feed off; then reset feeder at slightly lower setting.

TN

Troubleshooting

Trouble	Cause	Solution
In IR systems, low capacity.	MnO coating stripped from greensand grains due to insufficient regeneration; may be especially troublesome with high sulfide water.	Increase frequency of regeneration. Prefeed CL_2 with sulfide waters. Replace bed if required.
	Manganese greensand heavily iron-fouled.	Use CR method with dual-media bed to prevent iron fouling.
	Excessive grain growth due to high MnO buildup.	Increase frequency of regeneration. Bed replacement may be required.

TN

Responding to Red Water Complaints

- First step, be sure treatment processes are working properly
  - Then, investigate the distribution system
- Red or dirty water problems can be caused by
  - Iron or manganese in the water
  - Corrosive water
  - Iron bacteria in the distribution system
- Marble Test can tell stability of water
  - Langelier Saturation Index
  - Coupon test

TN

Responding to Red Water Complaints

- Growth of iron bacteria (Gallionella) inside water mains causes slimes to build up and eventually slough off
  - This leads to complaints of red water and slimes
  - Slime growths can be controlled by
    - Maintaining a free chlorine residual
      - If strong chlorine smell or taste, the solution is to add more chlorine to get past the breakpoint
    - Develop a unidirectional flushing program that starts where the water enters the distribution system, i.e. elevated tank
      - 2.5 ft/sec flushing velocity
      - 20 psi maintained in all parts of system during flushing to prevent backsiphonage

TN

Iron and Manganese Control Review Questions

1. What form are iron and manganese normally in when present in raw water?

2. How do iron and manganese become objectionable in a water system?

3. What are some of the principal aesthetic problems caused by excessive iron or manganese in water distributed to customers?

4. What are some of the consequences (other than customer complaints) when iron and manganese are oxidized at the treatment plant but not removed?

5. What are the maximum desirable levels of iron and manganese in drinking water furnished to customers?

6. What are the three principal methods of iron and manganese control?

7. What chemicals are principally used for oxidation of iron and manganese?

8. Explain the four steps used in removing of high concentrations of iron and manganese in water?

9. How does sequestration work?

Iron and Manganese Control Answers

1. Iron and manganese are normally in the dissolved form in raw water, where they are colorless and odorless.

2. When iron and manganese are oxidized, they change to a precipitate that will, in most cases, color the water yellow. Under some circumstances, the water may be turned brown or even black.

3. *Color in drinking water is generally disagreeable to customers, and they will refuse to drink it, even though it is microbiologically safe.

   *Brown stains will form on plumbing fixtures.

   *Brown stains will form in laundered clothes.

   *The presence of iron may turn tea and coffee dark black.

4. *Much of the precipitate will settle out in the water mains, then it will later be put back into suspension whenever there is a change in water flow.

   *The accumulation of sediment in mains can result in a reduction of flow capacity.

   *The sediment may clog meters and valves.

   *Bacteria that feed on the iron could increase discoloration.

   *Objectionable tastes and odors could be formed.

   *There will be an increase in chlorine demand in the system.

5. *Fe=0.3 mg/L
   *Mn= 0.05 mg/L

6. *oxidation, precipitation, and filtration
   *ion exchange
   *sequestering

7. *Chlorine
   *Chlorine dioxide
   *Ozone
   *Potassium permanganate

8. *Oxidation-the iron and/or manganese is oxidized by aerating the water or by adding an oxidizing chemical.

   *Detention-the water is held in a contact basin for a period of time to allow the reaction to be completed.

   *Sedimentation-most of the precipitate that has been formed is allowed to settle out in settling tanks.

   *Filtration-the material that remains in the water after sedimentation is removed with sand or multimedia filters.

9. In the sequestration process, polyphosphates or sodium silicates are added to the water before the water is exposed to air or another oxidant. The iron and manganese are not removed but are kept in the finished water.

Section 3

Fluoride

Fluoridation

California State University: Sacramento Manual
AWWA Water Supply Operations

1

Objectives

- History of Fluoridation
- Fluoridation Compounds
- Fluoridation Systems
- Auxiliary Equipment
- Chemical Storage
- Operations

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History of Fluoridation

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History of Fluoridation

- Dr. Frederick S. McKay initiated a study in 1908 of "Colorado Brown Stain" in Colorado Springs
- Important conclusions
  - Mottled teeth more resistant to dental decay
  - Life-long residents had stained teeth, more recent residents did not
  - High fluoride content of water identified in 1931

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History of Fluoridation

- In 1930's, Dr. H. Trendley Dean conducted the "21 Cities Study"
- Important conclusions
  - Optimum levels of fluoride for enhancing oral health (natural breakpoint at 1 mg/L)
  - 1.0 mg/L provided best combination of reduction in tooth decay (*caries*) and low risk of fluorosis
  - Established community fluorosis index (increased incidence at 2 mg/L)

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Fluoridation

- Controlled fluoridation started in 1945
  - Grand Rapids, Michigan
  - Newburgh, New York
  - Control cities of Muskegon and Kingston
- After fluoridating for 10 years, 60% reduction of caries in children who drank fluoridated water
- Mottling of teeth occurs with levels > 1.5 mg/L
- Steps should be taken to reduce fluoride in waters with more than 1.4-2.4 mg/L naturally
- Recommended MCL dependent on annual average maximum daily air temperature

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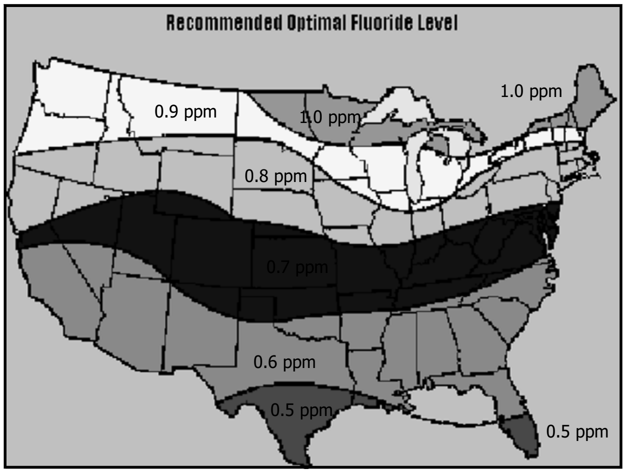

Fluoride Consumption

- If a person drinks 1 liter of water containing 1mg/L of fluoride, that person has consumed 1 mg of fluoride
- If a person drinks 2 liters of water containing 1 mg/L of fluoride, that person has consumed 2 mg of fluoride

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General Practices

- There are no Tennessee state regulations requiring water systems to fluoridate
- USEPA sets MCLs on fluoride, but there is no minimum level
  - Primary MCL = 4.0 mg/L
  - Secondary MCL = 2.0 mg/L
  - TN recommended feed rate = 0.7 mg/L

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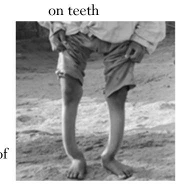
Fluorosis

- Dental fluorosis
  - Mottling of the teeth
  - Pitting of teeth, greater chance of tooth decay
  - Can occur at twice the optimal dosage
- Skeletal fluorosis
  - Crippling disease with rheumatic attacks, pain, and stiffness in the joints
  - Can occur at 2 mg/day for many years

Mild Dental Fluorosis
- White mottling of the teeth

Severe Dental Fluorosis
- Dark brown stains on teeth



Skeletal Fluorosis
- calcification of ligaments, change of bone structure

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Fluoridation Compounds

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Compounds Used to Feed Fluoride Ion

- Most commonly used compounds
  - Sodium fluoride
  - Sodium fluorosilicate
  - Hydrofluosilicic acid (most common)
- Factors to consider when choosing compound
  - Solubility of chemical in water
  - Operator safety
  - Ease of handling
  - Storage and feeding requirements
  - Costs
- Check natural fluoride level before feeding additional compound

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	Sodium Fluorosilicate	Sodium Fluoride	Hydrofluosilicic Acid
Form	Powder	Powder / crystalline	Liquid
Molecular weight	188.1	42.0	144.1
Purity, %	98-99	95-98	22-30 (by weight)
Fluoride Ion, %	60.7	45.3	79.2
Density	55-72 lb/ft^3	65-90 lb/ft^3	10.5 lb/gal
Solubility in Water, %	0.76	4.05	100 (infinite)
pH of saturated solution	3.5	7.6	1.2

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Sodium Fluoride (NaF)

- First compound used for fluoridation
- White, odorless crystals or powder
- Solubility constant at 4 grams per 100 mL
- Solutions have pH near neutral
- 98% pure
- Principle hazard is dust
- Used for saturators

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Sodium Fluorosilicate (Na_2SiF_6)

- Salt of fluorosilicic acid
- General by-product of fertilizer
- White, odorless crystalline powder
- Solubility varies with temperature
- 98% or higher purity
- Principle hazard is dust
- Most expensive

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Hydrofluorosilicic Acid (H_2SiF_6)

- Once referred to as "silly acid"
  - aka fluorosilicic acid
- Clear, colorless to slightly yellow liquid
- Pungent odor, fuming, will etch glass
- Corrosive, pH 1.0-1.5
- 18-23% pure
- Can cause burns, respiratory irritation
- More costly; easier to handle than dry chemicals

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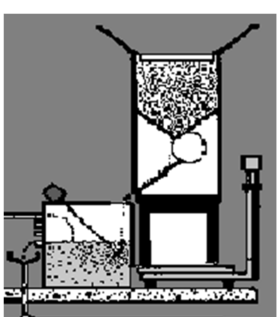
Fluoridation Systems



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Fluoridation Systems

- 3 different ways for water to be contain fluoride
  - Naturally present in raw water
  - Blending 2 water sources
  - Adding fluoride ion to water

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Chemical Feeders

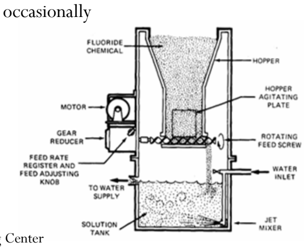
- Fluoride ions added by chemical solution or dry feeders
- Fluoride feeders must be very accurate
- Solution feeders – deliver a fixed amount of liquid
  - Positive displacement diaphragm pumps
  - Peristaltic pumps
  - Electronic pumps
- Dry feeders
  - Volumetric
    - Simpler, less expensive, less accurate, feed smaller amounts
  - Gravimetric
    - **More accurate** than volumetric, more expensive, require more space, amount fed based on weight of chemical

Dry Feeders

- Measure a given amount of dry chemical into a mixing tank where it forms a solution
- Requires a stirrer to provide good mixing
- Solution pumped or gravity-fed to clearwell

Dry Feeders

- Inspect and clean regularly to prevent breakdowns
- Inspect feed mechanism for signs of wear
- Inspect solution tank for precipitate buildup
- Calibrate feeder occasionally



Solution Feeders

- Small pumps feed solution from tank
  - Diaphragm pumps
    - cam speed or stroke is adjusted
  - Piston pumps
    - adjusting stroke length
    - can pump at very low rates
- Both are accurate & can pump against pressure
- Positive displacement

Solution Feeders

- Must ensure that chemical is completely dissolved to avoid clogging of feed lines and inconsistent dosages
  - 5-minute mixing time
- Must have vacuum breaker between tank and inlet valve as backflow preventer
  - No cross-connections

Acid Feed Systems

- Can be fed from shipping container
- Container set on scale to record usage
- Small systems may have to dilute
- Large systems can purchase tank truck and feed from day tank

Saturators

- Principle: saturated solution will result if water is allowed to trickle through a bed containing sodium fluoride
- NaF has a constant solubility and produces a fluoride solution of uniform strength
  - Fluoride solution will stabilize at 4% at normal temps
- Maintain a depth of 6-10 inches of sodium fluoride
- Should be stirred every day to prevent fluoride solids from building up on the bottom
- Make-up water $CaCO_3$ hardness
  - < 10 mg/L = no problems
  - 10-75 mg/L = scaling will occur and increase maintenance
  - > 75 mg/L = water must be softened before preparing a fluoride solution

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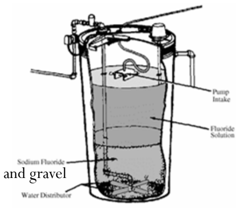
Saturators



- Two Types
  - Downflow saturators
    - Water flows from top to bottom
    - Bed of granular NaF sits on layer of sand and gravel
    - May need to be cleaned daily
    - **<u>Not approved for use in Tennessee</u>**
  - Upflow saturators
    - Water introduced at bottom
    - Bed of undissolved NaF on bottom of tank below which water is forced upward under pressure
    - Creates a cross-connection so must have siphon-breaker
    - Should only need cleaning per year

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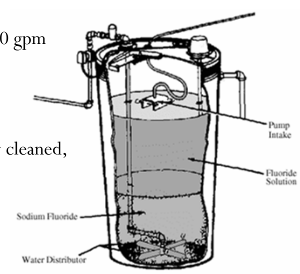
Saturators

- Maintain at least 6 inches of chemical at all times
- Saturators treating over 1,000 gpm need 10 inches
- Use crystalline NaF
  - less dust, does not compact
- Metering pumps periodically cleaned, worn parts replaced



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Auxiliary Equipment

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Safety Equipment

- Shower and eye wash facilities
- Chemical aprons
- Gauntlets
- Goggles
- Respirator or dust masks

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Scales

- Required for all systems except saturators
- Must have capacity to weigh full tank
- Measure to nearest pound
  - 1/2 pound for acid
- Connections to water lines & discharge lines must be flexible

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Dissolving Tanks

- Also known as solution tanks
- Dry chemicals from a feeder must be dissolved in a tank
- Minimum of 35 gallon tank
- Chemicals must be completely dissolved to avoid clogging or inconsistent feed rates

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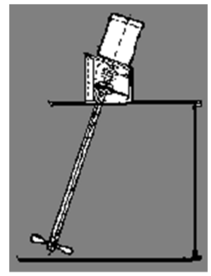
Mixers



- Mechanical mixer with stainless steel shaft and propeller
- In-line mixers also available

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Day Tanks (Acid)

- Hold enough chemical for 1 day or 1 shift
- Required to be set on a scale for weight measurement
- Polyethylene tanks most common
- Should be vented to outdoors
- All connections sealed to prevent corrosion

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Hoppers

- On dry feeders, hold chemical over feeder
- Should hold at least one bag of chemical to avoid spillage and excess dust
- May be installed with agitator to promote smooth and even flow

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Bag Loaders

- Helps operator lift chemical to fill hopper
- Holds one bag of chemical
- Door swings down, bag is attached by a rod through bottom of bag
- Bag is swung into position and cut open
- Requires operator to wear dust mask

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Fluoridation Chemical Storage

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Dry Chemical Storage

- Dry chemicals must be kept dry
- Bags should be stored as close to feeder as possible to minimize handling and dust
- Whole bags should be emptied into hopper to minimize spillage and dust
- Cut the top of the bag; do not tear
- Pour contents gently; do not toss the bags
- Good ventilation is required even if dust isn't bad

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Hydrofluorosilicic Acid Storage

- Containers should be kept tightly closed or vented to the outdoors due to corrosive vapors
- Should be stored away from switches, contacts and control panels

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Storage

- Never re-use empty fluoride containers
  They may still contain high levels of fluoride even after repeated rinsing

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Operation of Fluoridation Systems

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Fluoride Injection Point

- Apply fluoride after all treatment is complete
  - After filtration, before clearwell
- Should be as far as possible from lime or calcium hypochlorite application
- Injectors should be cleaned periodically to prevent precipitate buildup
- If injected into a pipe, inject into lower part

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Varying Concentrations

- Takes time for fluoride concentration in distribution system to stabilize
- Variations caused by inaccurate calibration, improper functioning of feeders and equipment
- Unfluoridated water introduced into the system
- Laboratory testing errors

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Low Concentrations

- Interferences with lab tests
  - Aluminum
- Inadequate chemical depth in a saturator
- Improper mixing in a solution tank
- Improper injection point

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High Concentrations

- Interferences with lab tests
  - Phosphates cause high readings with SPADNS
- Naturally occurring fluoride levels can vary
- Temperature
  - Low temp water can lead to high readings

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Fluoride Poisoning

- Can occur from malfunctioning equipment or failure to turn off feed system when flow is stopped
- Illnesses and at least one death blamed on high fluoride levels in public water supply

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Symptoms of Overexposure

- Chronic Toxic Exposure
  - Results from prolonged exposure to 2-8 times recommended level
  - Mottled teeth
  - Calcified ligaments and tendons
  - Vertebrae consolidation

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Safety – Fluoride Poisoning

- Fatal doses range from 4-5 grams (1 tablespoon)
  - Equivalent to approximately 2000 times the amount in water supply
  - Unlikely to get same symptoms from inhalation as from consumption, however symptoms should not be ignored
- Symptoms - consumption
  - Vomiting, stomach cramps, diarrhea
  - Very weak, trouble speaking, very thirsty, poor color vision
- Symptoms – inhalation
  - Biting pain in the nose with runny nose or nosebleed
  - Bad stomach cramps

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Control Tests

- Check raw fluoride level
- Check finished fluoride level
- Automatic monitors continuously record level
  - Have alarm if max concentration is exceeded

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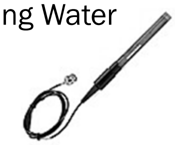
Analysis of Fluorides in Drinking Water



- Ion Selective Electrode method (ISE)
  - preferred because of fewer interferences
  - TISAB – Total Ionic Strength Adjustment Buffer
- Colorimetric (SPADNS)
  - interferences from phosphates & aluminum
- When Running Fluoride Tests:
  - Make sure glassware is clean and rinsed with distilled water
  - The use of phosphate-based detergents can interfere with test results (if using SPADNS)
  - Cold water can increase Fl reading; allow sample to come to room temperature before testing

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Fluoride Vocabulary

______1. Anti-siphon device
______2. Backflow
______3. Colorimetric Method
______4. Day Tank
______5. Dental Carries
______6. Diaphragm Pump
______7. Electrode Method (Ion Specific)
______8. Fluorosis
______9. Fluoridation
______10. Fluorosilicic Acid
______11. Gravimetric Dry Feeder
______12. Ion
______13. Ion-Exchange Water Softener
______14. Mottling
______15. Piston Pump
______16. Positive-Displacement Pump
______17. SPADNS Method
______18. Saturator
______19. Sodium Fluoride
______20. Sodium Silicofluoride
______21. Vacuum Breaker
______22. Volumetric Dry Feeder

A. A mechanical device that prevents backflow due to a siphoning action created by a partial vacuum that allows air into the piping system, breaking the vacuum.
B. A piece of equipment that feeds a sodium fluoride solution into water for fluoridation. A layer of sodium fluoride is placed in a plastic tank and water is allowed to trickle through the layer forming a constant solution, which is fed to the water system.
C. The staining of teeth due to excessive amounts of fluoride in the water.
D. Chemical feeder that adds specific weights of dry chemical.
E. A tank used to store a chemical solution of known concentration for feed to a chemical feeder. The tank usually stores sufficient chemical solution to properly treat the system's water for a least one day.
F. Chemical feeder that adds specific volumes of dry chemical.
G. A dry chemical used in the fluoridation of drinking water. It is derived from fluorosilic acid. It is also called Sodium Fluorosilicate.
H. A colorimetric procedure used to determine the concentration of fluoride ion in the water. This is also the name given to he chemical reagent used in the test.
I. The addition of a chemical to increase the concentration of fluoride ion in drinking water to a predetermined optimum level to reduce the incidence of dental caries in children.
J. A dry chemical used in fluoridation of drinking water. It is commonly used in saturators.
K. A type of piston, diaphragm, gear or screw pump that delivers a constant volume with each stroke. These pumps are used as chemical solution feeders.
L. A treatment unit used to remove calcium and magnesium from water using ion-exchange resins.
M. Staining or pitting of the teeth due to excessive amounts of fluoride in the water.
N. A positive displacement pump that uses a piston moving back and forth in a cylinder to deliver a specific volume of liquid.
O. An atom that is electrically unstable because it has more or less electrons than protons.
P. A strongly acidic liquid used to fluoridate drinking water. This chemical was called Hydrofluosilic Acid or "Silly Acid".
Q. A pump in which a flexible rubber, plastic or metal diaphragm is fastened at the edges in a vertical cylinder. As the diaphragm is pulled back, suction is exerted and the liquid is drawn into the pump. When it is pushed forward, the liquid is discharged.
R. Another term for vacuum breaker.

S. The medical term for tooth decay.
T. A hydraulic condition, caused by a difference in pressures that causes nonpotable water or other fluid to flow into a potable water system.
U. A laboratory procedure for determining the fluoride concentration in water. This method has less interference and is generally more accurate than other methods.
V. Based on a reaction in which a dye lake is formed with zirconium and a dye. The colors produced by different concentrations of fluoride ions are all shades of red. A photometer is used to measure the difference in color.

Fluoride Review Questions

1. Name two types of Fluorosis and a description of each.
   -
   -

2. What are the maximum contaminant levels for fluoride as set by the USEPA?
   Primary MCL –

   Secondary MCL –

3. List the two factors that determine the total amount of fluoride a person consumes in a day.
   -
   -

4. List the three fluoride chemicals used in the US and describe each.
   -
   -
   -

5. Of the two types of dry feeders (volumetric and gravimetric) which is more accurate?

6. List five types of safety equipment recommended when handling fluoride chemicals.
   -
   -
   -
   -
   -

7. Why should fluoride be injected as far as possible from the addition of lime or calcium hypochlorite?

8. What is the minimum mixing time recommended for fluoride solutions?

9. Which of the following can cause erroneously high fluoride readings?
   (a) Aluminum
   (b) Chlorine
   (c) Polyphosphates
   (d) Sodium

10. How often should a fluoride test be run on finished water?

11. Which of the following are characteristics of acute toxic exposure to fluoride?
   (a) Mottled teeth
   (b) Sharp, biting pains in the nose
   (c) Vomiting
   (d) b and c
   (e) All of the above

Fluoride Math

1. A water plant produces 2000 gallons per minute and wants to add 1.1 mg/L of fluoride to the water using sodium fluorosilicate. What will the fluoride feed rate be in lbs/day?

2. What is the fluoride feed rate in lbs/day using fluorosilicic acid if the plant rate is 1.0 MGD, the natural fluoride in the water is 0.2 mg/L, and the desired fluoride level is 1.2 mg/L?

3. A water plant produces 1.0 MGD. What will the sodium fluoride feed rate be from a saturator (in gpd) to obtain a 1.0 mg/L fluoride dose in the finished water?

4. A plant uses 65 lbs of sodium fluorosilicate in treating 5,540,000 gallons of water in one day. What is the calculated dosage in mg/L?

Answers to Fluoride Questions

Vocabulary

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

Answers to Fluoride Review Questions

1. Dental Fluorosis – mottling of the teeth due to mild overexposure to fluoride
   Skeletal Fluorosis – crippling disease characterized by rheumatic attacks, pain and stiffness; caused by chronic overexposure to fluoride
2. The primary MCL for fluoride is 4 mg/L to prevent skeletal Fluorosis. The secondary MCL is 2 mg/L to prevent dental Fluorosis.
3. The total amount of water a person consumes in a day and the amount of fluoride in the water determine the total amount of fluoride a person consumes in a day.
4. Sodium Fluoride (NaF) – white, odorless, crystalline solid; solubility is a constant 4% which allows it to be used in a saturator
   Sodium Fluorosilicate (Na_2SiF_6) – white, odorless, crystalline solid; salt of fluorosilicic acid
   Fluorosilicic Acid (H_2SiF_6) – pH of 1-1.5, clear, colorless to slightly yellow liquid
5. A gravimetric feeder is more accurate, but also more expensive.
6. Safety equipment needed when handling fluoride are: shower and eye wash, goggles or face shield, gauntlets, chemical apron, respirator or dust mask
7. Fluoride will form an insoluble precipitate with chemicals containing calcium.
8. A 5 minute mixing time is recommended for fluoride solutions.
9. Polyphosphates can cause erroneously high fluoride readings.
10. Daily fluoride tests are required.
11. Sharp, biting pains in the nose and vomiting may indicate acute toxic fluoride exposure.

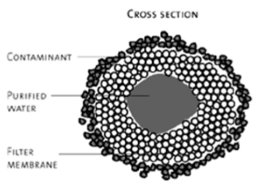
Answers to Math

1. 44.19 lbs/day
2. 45.9 lbs/day
3. 55.6 gpd
4. 0.84 mg/L

Section 4

Membrane Filtration

MEMBRANE TECHNOLOGY



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OBJECTIVES

- History and Advantages of Membrane Technology
- Membrane Configurations
- Membrane Science and Theory
- Membrane Materials and Module Types
- Membrane Operations
- Membrane Integrity Testing
- Process Residuals
- Regulatory
- Troubleshooting

2

HISTORY OF MEMBRANE TECHNOLOGY

3

HISTORY

- Mid-late 1980's- membrane filtration used primarily for industrial applications such as the wine and juice industries
- Companies such as Aquasource and Memcor began to market membrane technology for treatment of drinking water in the early 1990's
- Small scale pilot studies at drinking water facilities showed membranes improved filtrate quality and reduced DBP's
- First full scale microfiltration membrane facility, the Saratoga WTP in California, went online in 1993
- In 1994 a Rice University study showed that low pressure membrane filtration would be cost-effective at capacities of 5 MGD

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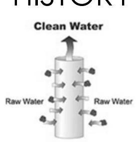
HISTORY



Above: A strand of membrane in action
Below: A cassette housing membranes

- In 1997 a study showed that if membranes were installed downstream of conventional coagulation, flocculation and sedimentation that the membrane could be operated at a higher rate, making it cost effective for even 50 MGD capacity
- The potential for large scale membrane facilities resulted in the formation of additional membrane manufacturers and improvements in membrane technology
- Companies such as Pall, Zenon, and Koch began to develop new membrane technology
- The largest low pressure membrane filtration plant to date is in Azerbaijan.
  - It treats 150 + MGD

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WHY MEMBRANE TECHNOLOGY?

- **Regulatory**- the SWTR requires a higher level of turbidity and particulate removal. Membranes can consistently obtain that level of turbidity removal.
- **Cost**- since the early 1990's the capital cost of membrane treatment has decreased. In addition, the implementation of innovative backwash and cleaning strategies have reduced the operational costs.
- **Operational flexibility**- low pressure membrane filtration processes are highly flexible and can be used in conjunction with other processes to achieve specific treatment objectives. In addition, membrane facilities can be easy to operate because the process is not dependent on water chemistry or flow.

6

OPERATIONS

Membrane Filtration

- Treatment is independent of pre-treatment conditions and raw water turbidity.
- Pore size in membranes forms an effective barrier to cyst sized particles.
- No need for a filter to waste step at the beginning of a filtration run.

Conventional Filtration

- Requires optimized chemical pretreatment (coagulation, flocculation, sedimentation).
- Operators must adjust treatment for changing water conditions.
- Giardia and Cryptosporidium may pass through filter.
- Must filter to waste prior to returning to the filtration cycle after backwashing.

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OPERATIONS

Membrane Filtration

- Increased turbidity may have no effect on performance or it may cause a decline in flux or a decrease in time interval between backwashing and cleaning.
- Goal is to maintain finished water productivity, quality of the filtrate remains the same.

Conventional Filtration

- Increased turbidity will require additional coagulant to be added, or increased flocculation/settling, shorter filter runs, increased backwashing or may result in reduced finished water quality.
- Goal is to maintain finished water quality.

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MEMBRANE CONFIGURATIONS

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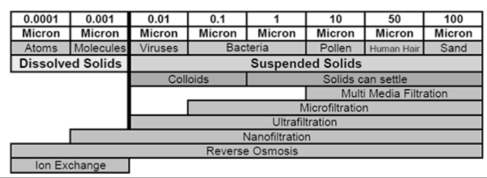
PORE SIZE CLASSIFICATION

- Membranes are classified by the size of the pore spaces
- From largest to smallest pore spaces
  - Microfiltration
  - Ultrafiltration
  - Nanofiltration
  - Reverse osmosis



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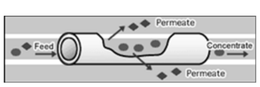
INSIDE-OUT FILTRATION



- A high cross-flow velocity over the membrane surface prevents membrane fouling.
- Easier to backwash
- This makes inside-out filtration suitable for concentration and purification of highly concentrated solutions

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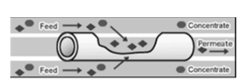
OUTSIDE-IN FILTRATION



- Utilizing the larger area of the outer surface of the membrane fiber, the filtration load per unit area may be reduced
- Lower head loss through the module
- These features make this mode of operation well suited for high volume water clarification
- It is more difficult to backwash and control flow to the membrane
- Cleaning technique such as 'air-scrubbing' may be utilized

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CROSSFLOW FILTRATION

- Feed water is pumped with a crossflow tangential to the membrane
- The water that does not pass through the membrane is recirculated as concentrate and blended with the feed water
- Pressure on the concentrate side is conserved and deducted from the total head requirement
- A bleed stream can be used to control the concentration of solids in the recirculation loop
- Concentrate can be wasted at any time from the recirculation loop

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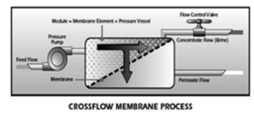
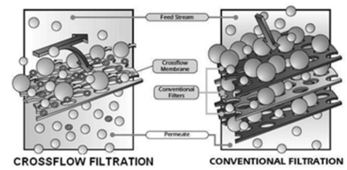
CROSSFLOW FILTRATION

- In some cases, crossflow filtration is used
- The direction of the flow can help to prevent the deposition of materials on the membrane surface thereby reducing fouling





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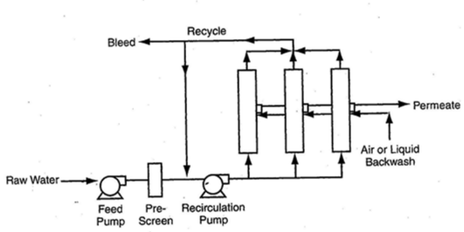
CROSSFLOW FILTRATION



Pressure driven system configuration with crossflow

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DIRECT FLOW FILTRATION

- Also called dead-end or deposition mode
- Water is applied directly to the membrane
- All feed water passes through the membrane between backwashings
- There is 100% recovery of this water, however, some must be used for backwashing
- Considerable energy savings because recirculation is not required

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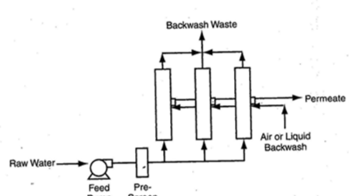
DIRECT FLOW FILTRATION



Pressure driven direct flow

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SUBMERSIBLE MEMBRANE FILTRATION

- Fibers are submerged in the feed water
- A vacuum is applied to the inner lumen of the fibers to create a pressure differential necessary for filtration to occur
- The outside of the fibers are scoured by air periodically or continuously
- Backwashing with the permeate is conducted at regular intervals

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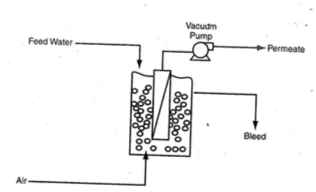
SYSTEM CONFIGURATION



Direct flow submersible

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MEMBRANE SCIENCE AND THEORY

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MEMBRANES: SCIENCE AND THEORY

- Pure water transport across a clean porous membrane is affected most by the trans-membrane pressure and the viscosity of the water
- **Trans-membrane pressure**: The force which drives liquid flow through a membrane.
  - During filtration, the feed side of the membrane is under higher pressure than the permeate side. The pressure difference forces liquid through the membrane.

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FLUX

- The word *flux* comes from Latin: *fluxus* which means “flow”
- Volumetric flux describes the volume of flow across a unit of area
- Typical units for membrane volumetric flux are gallons per square foot of membrane per day or liters per square meter of membrane per hour

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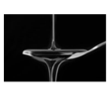
TEMPERATURE EFFECTS



- Think about maple syrup, when maple syrup is cold it is very thick and viscous
- If you put it in the microwave and warm it up it pours much more easily

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TEMPERATURE EFFECTS

- Water behaves much like maple syrup
- The viscosity or resistance to flow of water is dependent on temperature
- The colder the water, the higher the viscosity
- Viscosity will affect membrane performance by either reducing the flux or by requiring an increase in trans-membrane pressure to keep the flux constant

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SEASONAL EFFECTS

- Higher trans-membrane pressures may be required in the winter to offset the effect of temperature on the viscosity of the water
- Membrane fouling may also change with season and temperature
- Source water is variable, there is seasonal variation in the amounts of organics, metals, nitrates, etc.

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SYSTEM OPERATIONS

The two primary operational concepts are:

- To operate at a constant pressure
- To operate at a constant flux

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CONSTANT PRESSURE

Advantages:

- Feed pumps can be sized to maintain the constant pressure with simple on/off controls
- Energy requirements are constant

Disadvantages:

- Permeate flow will decrease over time due to membrane plugging prior to backwash
- Output of plant is reduced

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CONSTANT FLUX

Advantages:

- No over-sizing of the system is needed
- Out-put remains the same
- Most often used by full scale membrane plants

Disadvantages:

- Feed pressure must increase to maintain constant flux between backwashes
- Energy efficiency decreases with increased trans-membrane pressure

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MEMBRANE MATERIALS AND MODULE TYPES

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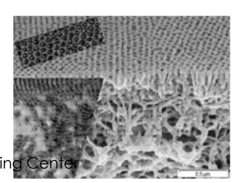
MEMBRANE MATERIALS

- The most common membrane materials are either organic polymers or ceramic materials
- The polymer membrane materials vary with resistance to fouling, operating temperature and pH ranges and resistance to oxidants



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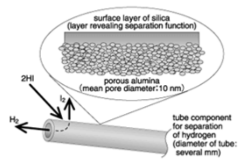
POLYMER MATERIALS

Membrane material	Type	Oxidant tolerance	pH range	Resistance to fouling
PVDF	MF/UF	Very high	2-11	Excellent
Polypropylene(PP)	MF	Low	2-13	Acceptable
Polyethersulfone (PES)	UF	High	2-13	Very Good
Polysulfone (PS)	UF	Moderate	2-13	Good
Cellulose Acetate (CA)	UF	Moderate	5-8	Good

CERAMIC MEMBRANES

- Ceramic membranes are made by heating materials like aluminum oxide, titanium dioxide or carbon composites into a brittle clay like ceramic form
- The ceramic membranes are thicker and have a greater resistance to water transport, so the trans-membrane pressures may need to be increased
- The benefits of ceramic membranes include: that they are easier to clean and maintain than polymer membranes, and that they are able to withstand higher temperatures and pressures and can operate at a pH of 0-14

CERAMIC MEMBRANES



Ceramic Membrane Elements and Housings

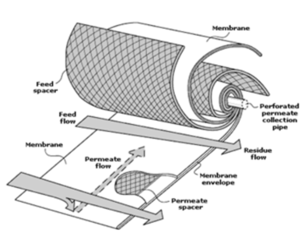
MEMBRANE MODULE TYPES

There are several commercially available membrane technologies including:

- Spiral wound
- Tubular
- Hollow fiber
- Plate and Frame
- Cassette

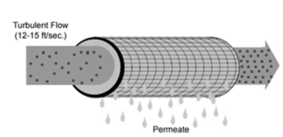
SPIRAL WOUND MEMBRANE

- Not commonly used for microfiltration or ultrafiltration
- The flat sheet nature makes it difficult to keep clean



TUBULAR MEMBRANE MODULE

- Rather than a sheet of microfiltration membrane, the membrane is made in a tube fit into a module
- The membrane is on the inside of the tube with a HDPE support tube
- This arrangement allows the membrane to be backwashed which controls fouling



TUBULAR MEMBRANE MODULE

- The membranes which are composed of polymer or ceramic are placed inside plastic or stainless steel modules and sealed by a gasket or ring clamp
- The tubular membranes have relatively large inner diameters (1-2.5 cm)
- The feed water which is under pressure flows through the inner lumen of the tube
- The permeate is collected in the outer shell of the module

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TUBULAR MEMBRANE MODULE

Advantages

- Large diameter of channels allows for treatment of water with large particles or high solids
- High cross flow velocities (up to 5 m per second) can be used to control fouling
- Easy to clean because of large diameter channels

Disadvantages

- Low surface area to volume ratio or "packing density" of membrane

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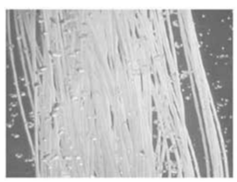
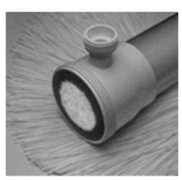
HOLLOW FIBER MEMBRANE

- Can be arranged in a tubular housing or as a cassette type module
- Can be backwashed to prevent fouling



Full Scale Unit

Bench Scale Unit



HOLLOW FIBER MEMBRANE

- Consists of several hundred to several thousand fibers encased in a module
- The fibers are bonded at each end with an epoxy or urethane resin
- The inner lumens or internal fiber diameters are very small (0.4 to 1.5 mm)
- There are two different regimes in hollow fiber filtration: inside out, and outside in

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HOLLOW FIBER MEMBRANE

Advantages

- Low pressure drop across the module
- High surface to volume ratio or "packing density"
- Low trans-membrane pressures 3-15 psi
- Fibers can be backwashed

Disadvantages

- Small tube diameter are susceptible to plugging
- The large number of fibers may cause difficulty in detecting the loss of membrane integrity

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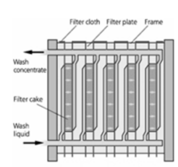
PLATE AND FRAME TYPE

- Membrane filter plates: a flexible membrane is fixed to the support body
- Materials for the membranes include Polypropylene, synthetic rubber (for example NBR, EPDM) or thermoplastic elastomer (TPE)
- The membrane is impermeable and serves to compress the cake within the chamber after the filtration process is complete
- Most often used in industrial applications, or wastewater, not used in water treatment



Filter cake washing in a plate and frame filter press

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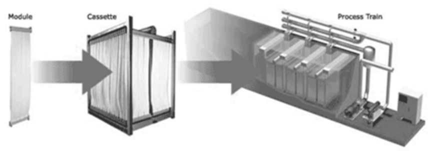
CASSETTE TYPE MEMBRANE



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MEMBRANE OPERATIONS

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OPERATIONS

Modes of Operation

- Filtration
- Backwash
- Air scrub
- Chemically enhanced backwash (some systems)
- Chemical clean in place (CIP)
- Membrane Integrity Testing

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OPERATIONS

- Generally filtration, backwash and air scrubbing are automatically controlled by the system based on operator selected points such as:
  - Trans-membrane pressure (TMP)
  - Flux rate or volume filtered
  - Filter run time
- Clean in place is usually selected manually.
- Integrity testing is conducted automatically or at operator selected intervals.

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OPERATIONS

- Data Collection
  - Careful data collection and good recordkeeping are important to the successful long-term performance of membrane systems
  - Data should be collected as soon as the unit begins service and should include:
    - Flow of feed water, filtrate, and retentate
    - Temperature
    - Turbidity of feed and filtrate
    - Results of integrity testing
    - TMP

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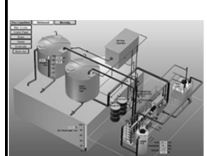
OPERATIONS



- Most data is collected automatically using a SCADA system
- It is important to collect both pre and post cleaning data

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PUMP REQUIREMENTS

- **Variable speed centrifugal:**
  - used to deliver raw water to membranes at the required flow and pressure (usually 20 -30 psi)
- **Permeate vacuum pump**
  - used for systems that operate under a vacuum, one dedicated to each membrane bank, sized to produce the permeate flow of each membrane bank
- **Recirculation pump**
  - used for inside-out crossflow configurations, one dedicated for each membrane bank
- **Backwash pump**
  - used for backwashing, may use liquid or gas medium

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MEMBRANE BACKWASHING

- For most systems it is performed automatically
- Can be set for a run time, usually every 30-120 minutes
- Can also be set to backwash when a certain trans-membrane pressure is reached or when a certain amount of permeate has been produced
- The duration of backwash lasts from 1-5 minutes
  - Do not have to filter waste after backwash

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BACKWASHING

- The permeate collected in a reservoir is employed to backwash the membrane
- A liquid stream under pressure from a backwash pump dislodges solids from the surface of the membrane
- For submerged systems, backwashing occurs for 30 seconds every 15 minutes to several hours
- The backpulsing dislodges any deposition that has accumulated

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PRETREATMENT

- **Prefiltration**
  - may be required to remove large particles that could plug the inlet to the fibers.
- **pH adjustment**
  - may be required to keep feed water in the optimum range for the membrane polymer type.
- **Adsorption and Coagulation**
  - coagulants and PAC can be used to prevent fouling of the membrane.
- **Pre-oxidation**
  - used to oxidize metals such as iron and manganese so that they do not form in the membrane or the permeate.

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POST TREATMENT

Disinfection: required by State and Federal Regulations

Optional additions:

- Fluoridation
- Corrosion Control

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REDUCTIONS IN MEMBRANE PRODUCTIVITY

Reductions in membrane productivity can result for a number of reasons including:

- Membrane Compaction
- Membrane Fouling
  - Inorganic fouling
  - Organic fouling
  - Biofouling

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MEMBRANE COMPACTION

- Membrane compaction is a physical compression of the membrane
  - This compression results in a decrease in flux
  - The rate of compaction is directly proportional to an increase in temperature and pressure
- Compaction occurs naturally over time requiring a greater feed pressure
- Compaction is permanent and can occur quickly in membranes if operated at higher pressures for any extended period of time
- Usually membrane compaction results in a few percent flux decline, and has strongest effect during the initial operating period

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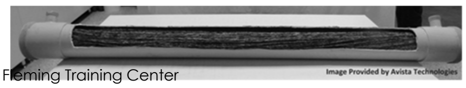
FOULING

- Fouling is defined as the reduction in flux at constant pressure resulting from the adsorption or deposition of suspended matter in the membrane pores or on the membrane surface
- The three fouling mechanisms are:
  - Pore adsorption
  - Pore blocking
  - Cake formation



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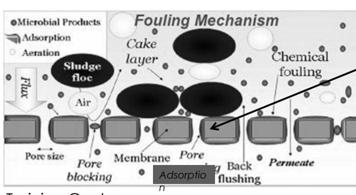
FOULING

- **Pore adsorption**
  - occurs when particles smaller than the pore deposit themselves on the pore walls which reduces the effective size of the pores



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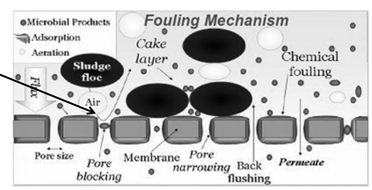
FOULING

- **Pore blocking**
  - occurs when particles as large as the pore become lodged in the pore and block the passage
  - the effective number of pores is reduced



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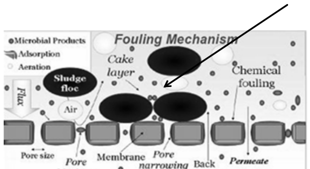
FOULING

- **Cake formation**
  - this occurs when particles too large to enter the pores become deposited on the surface of the membrane
  - Cake formation results in a reduced flux across the membrane



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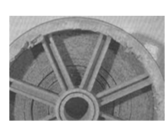
INORGANIC FOULING

- Inorganic fouling can occur when inorganic particles such as silt, clay, iron, manganese, nitrates, etc are deposited on the surface of the membrane



Membrane fouled with inorganic material.

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ORGANIC FOULING

- Organic fouling occurs when natural organic matter (NOM) in source water prevents flux across the membrane by plugging pores in the membrane

A membrane severely fouled by organics

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BIOFOULING

- Biofouling occurs when microorganisms adhere to the membrane surface and begin to grow colonies on or in the membrane
  - the microbes will eventually obstruct the flow through the membrane.

Extreme biofouling of membrane.

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CLEANING

- When fouling materials can no longer be removed by backwashing, chemical cleaning is required
- Considerations include the cleaning and rinse volumes, temperature of cleaning water, reuse and disposal of chemicals
- Many different chemicals can be used including detergents, acids, bases, oxidizing agents and enzymes
- Chlorine is often used on PVDF membranes in concentrations from 2-2000 mg/L
- Heating the cleaning solution to 35-40°C can enhance cleaning effectiveness

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CLEANING CHEMICALS

- **Acids**
  - citric acid is most commonly used, it works well on inorganic contaminants such as iron. Other acids such as hydrochloric or sulfuric may be used
- **Bases**
  - caustic soda is the most commonly used, also good on inorganics
- **Oxidants**
  - free chlorine is very effective at removing organic contaminants
- **Surfactants**
  - release contaminants instead of dissolving them. Works well on PAC or if the membrane has a limited pH range

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MEMBRANE INTEGRITY TESTING

66

MEMBRANE INTEGRITY TESTING

- One of the most critical aspects of employing membrane technology is integrity testing
- Integrity testing ensures that the membranes are an effective barrier between the feed water and the permeate being produced

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INTEGRITY TESTING

There are several methods that can be used to monitor membrane integrity including:

- Turbidity monitoring
- Particle counting
- Particle monitoring
- Biological monitoring
- Air pressure decay testing
- Diffusive air flow testing
- Water displacement testing
- Bubble testing
- Sonic wave sensing
- Visual inspection

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TURBIDITY MONITORING

- Most commonly used method of measuring the performance of filtration systems
- Most membrane systems can provide permeate with turbidities less than 0.1 NTU
- Use of turbidity as the sole method for determining membrane integrity does not provide adequate sensitivity to detection of small pinholes in membrane fibers

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PARTICLE COUNTING AND MONITORING

- Multichannel particle counting is a standard particle counting method used in many water treatment plants
- The advantage is that it is a continuous online measurement, however, several sensors are required to establish the sensitivity needed to detect loss of membrane integrity
- Another method of measuring particles is particle monitoring which is based on dynamic light obscuration
- Particle monitors are usually cheaper and easier to operate than particle counters, however, they also require multiple sensors for the sensitivity level of membranes
- Particle counters measure the number and size of particles, while turbidimeters measure the volume of particles

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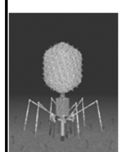
BIOLOGICAL MONITORING



- One of the most sensitive methods for evaluating membrane integrity is viral seeding
- Viruses at densities in the range of 106-107 PFU/mL are introduced into the effluent
  - **Plaque:** an area of cells in a layer which displays a cytopathic effect
  - **Plaque-forming unit (PFU):** a virus or group of viruses which causes a plaque

At various times, samples are collected from the permeate to determine if those viruses have passed through the membrane

Often used for pilot- or bench scale studies, because you don't want to introduce viruses into water that is being consumed

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AIR PRESSURE DECAY TESTING

- The membrane module is pressurized to approximately 15 psi from the feed side
- Minimal loss of held pressure (usually less than 1 psi every 5 minutes) at the filtrate side indicates a passed test
- A significant decrease of the held pressure indicates a failed test
  - >0.5 psi lost during test indicates a failed integrity test

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DIFFUSIVE AIR FLOW TESTING

- The diffusive air flow test uses the same concept as the air pressure decay test but it is performed by monitoring the displaced liquid volume caused by leaking air from the compressed membrane fibers
- This test is more sensitive than air pressure decay because it is easier to measure small changes in liquid volume than small changes in air pressure

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BUBBLE TESTING

- Bubble testing can identify a fiber or seal location that is leaking in a membrane module
- This test is usually run after the compromised module is identified by another monitoring method such as air pressure decay or a sonic sensor
- Basically the module is submerged while air is passed through it, bubbles formed by escaping air identify the location of the leaking fiber
- The leaking fiber is either sealed using epoxy glue or by inserting a pin of the same diameter into the inlet

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SONIC WAVE SENSING

- Sonic sensor equipment consists of a sound wave sensor attached to a headphone
- The headphones are manually placed at the top, middle, and bottom of the membrane module during the air pressure decay test
- The headphones can detect sound waves produced by air escaping from a compromised membrane
- This test has to be followed by the bubble test and visual inspection

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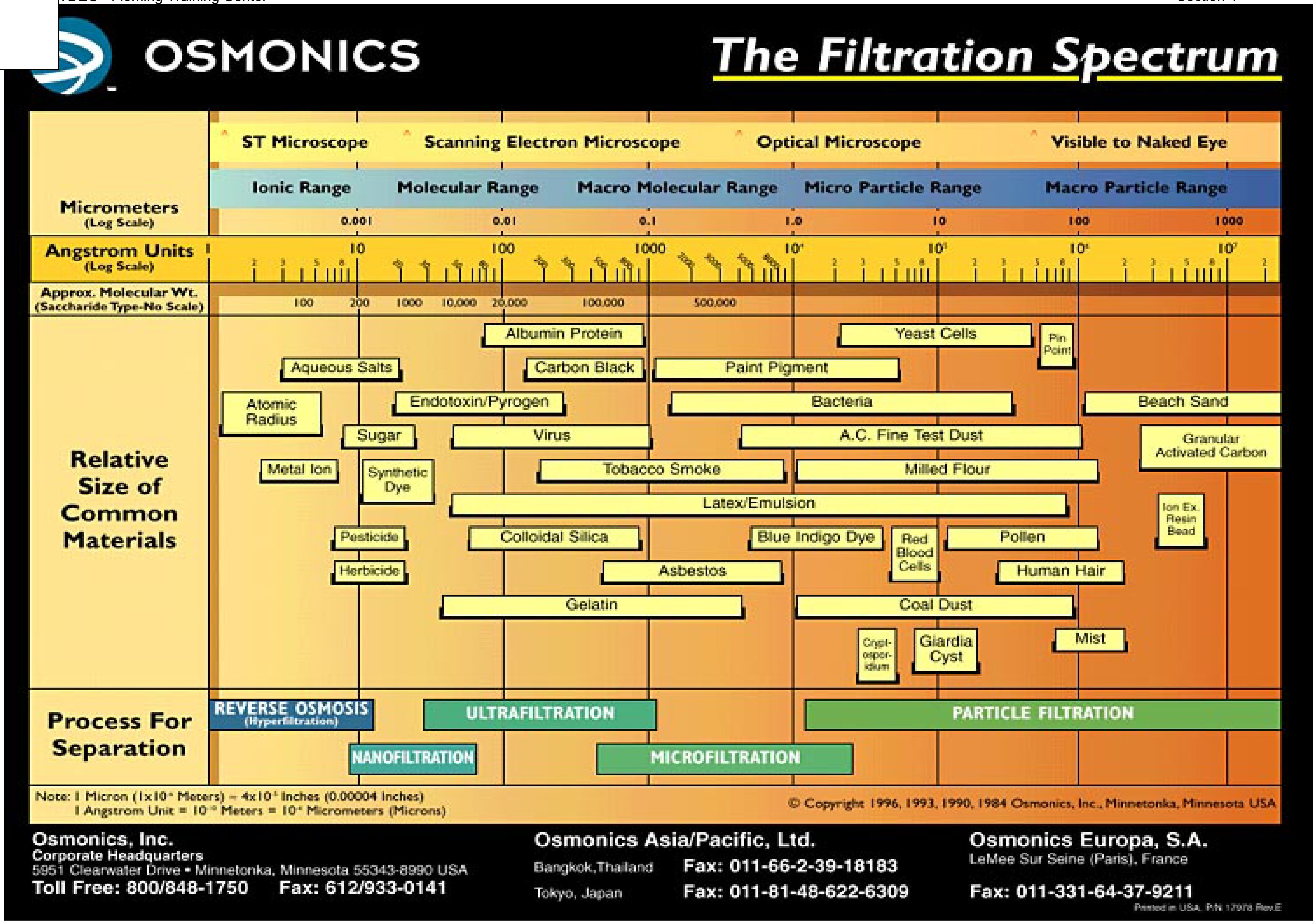
VISUAL INSPECTION

- If a pressure based integrity test is used, visual inspection can be conducted simultaneously by watching the fibers for bubbles escaping
- Often the module may have to be removed from the housing so that visual inspection can be performed


OSMONICS
The Filtration Spectrum
ST Microscope
Scanning Electron Microscope
Optical Microscope
Visible to Naked Eye
Ionic Range
Molecular Range
Macro Molecular Range
Micro Particle Range
Macro Particle Range
Micrometers
(Log Scale)
0.001
0.01
0.1
1.0
10
100
1000
Angstrom Units
(Log Scale)
1
10
100
1000
Approx. Molecular Wt.
(Saccharide Type-No Scale)
100
200
1000
10,000
20,000
100,000
500,000
Relative Size of Common Materials
Albumin Protein
Yeast Cells
Pin Point
Aqueous Salts
Carbon Black
Paint Pigment
Atomic Radius
Endotoxin/Pyrogen
Bacteria
Beach Sand
Sugar
Virus
A.C. Fine Test Dust
Granular Activated Carbon
Metal Ion
Synthetic Dye
Tobacco Smoke
Milled Flour
Latex/Emulsion
Ion Ex. Resin Bead
Pesticide
Colloidal Silica
Blue Indigo Dye
Red Blood Cells
Pollen
Herbicide
Asbestos
Human Hair
Gelatin
Coal Dust
Cryptosporidium
Giardia Cyst
Mist
Process For Separation
REVERSE OSMOSIS
(Hyperfiltration)
ULTRAFILTRATION
PARTICLE FILTRATION
NANOFILTRATION
MICROFILTRATION
Note: 1 Micron (1x10⁻⁶ Meters) ≈ 4x10⁻⁵ Inches (0.00004 Inches)
1 Angstrom Unit = 10⁻¹⁰ Meters = 10⁻⁴ Micrometers (Microns)
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Section 5

Softening

SOFTENING

Hardness

Lime-softening

Ion Exchange

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OBJECTIVES

- Water Hardness
  - Effects of hard water
  - Minerals causing hard water
  - Various types of hardness
- Softening Process
  - Chemical precipitation
  - Equipment used for softening
  - Ion Exchange
  - Operations

2

WATER HARDNESS

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TN Department of Environment & Conservation

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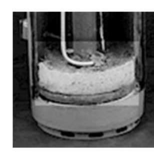
WATER HARDNESS

- Most common customer complaints
  - Scale formation on cooking utensils, water heaters, and water fixtures
  - Increases amount of soap needed



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WATER HARDNESS

- Hardness is picked up as water passes over geological formations of limestone, dolomite, and other magnesium-bearing minerals
- Groundwater usually has more hardness than surface water because of the extended period of time it is exposed to the geological formation

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WATER HARDNESS

Expressing Hardness Concentration

- Hardness is expressed as mg/L as $CaCO_3$
- Also expressed as grains per gallon
  - 17.12 mg/L = 1 grain per gallon
  - More important when doing ion exchange

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HARDNESS

Description	Hardness (mg/L as $CaCO_3$)
Extremely soft to soft	0 - 45
Soft to moderately soft	46 - 90
Moderately hard to hard	91 - 130
Hard to very hard	131 - 170
Very hard to excessively hard	171 - 250
Too hard for domestic use	Over 250

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MAIN HARDNESS CAUSING COMPOUNDS:

- Calcium bicarbonate - $Ca(HCO_3)_2$
- Magnesium bicarbonate - $Mg(HCO_3)_2$
- Calcium sulfate - $CaSO_4$
  - gypsum
- Magnesium sulfate - $MgSO_4$

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TYPES OF HARDNESS

Calcium Hardness vs. Magnesium Hardness

- Water hardness is caused by calcium ions (Ca^{2+}) and magnesium ions (Mg^{2+}) that have combined ions in water

$$\text{Total hardness} = \text{calcium hardness} + \text{magnesium hardness}$$

- Other cations may cause hardness but are not usually present in large enough concentrations to be significant

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CARBONATE HARDNESS

- Caused primarily by the bicarbonate salts of calcium and magnesium
  - Calcium bicarbonate - $Ca(HCO_3)_2$
  - Magnesium bicarbonate - $Mg(HCO_3)_2$
  - Calcium carbonate - $CaCO_3$
- Caused by the alkalinity present in water up to the total hardness
- Sometimes called temporary hardness because it can be settled out by heat or removed by lime alone

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NONCARBONATE HARDNESS

- Measure of calcium and magnesium salts other than carbonate and bicarbonate salts
  - Calcium sulfate - $CaSO_4$
  - Calcium chloride - $CaCl_2$
  - Magnesium sulfate - $MgSO_4$
  - Magnesium chloride - $MgCl_2$
- Portion of the total hardness in excess of the alkalinity
- Also called permanent hardness because it cannot be removed or precipitated by heat or by lime alone

$$\text{Total hardness} = \text{carbonate hardness} + \text{bicarbonate hardness}$$

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OBJECTIONS TO HARD WATER

- Scale formation
  - Decreases flow through pipes
  - Leaves scale on dishes
  - Magnesium hydroxide precipitates at 140-150ºF, which increases heating costs for water heaters
- Effect on Soap
  - Causes "soap scum"
  - Reduces soap efficiency
  - Synthetic detergents have sequestering agents that tie up the hardness ions

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OBJECTIONS TO SOFT WATER

- Leaves slippery feeling on skin
- Usually very corrosive, even moderately soft water can be corrosive to plumbing and pipes
- Steps should be taken to reduce corrosion and ensure compliance with the Lead & Copper Rule

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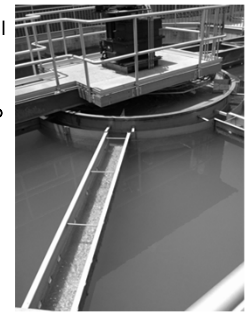
DECIDING TO SOFTEN

- Chemical precipitation method will also remove iron and manganese, radionuclides, etc
- Cost may be too great to justify to customers
- Lime-softening occurs in pH range of 10-11
  - Same pH for Fe & Mn removal



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SOFTENING PROCESS

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CHEMICAL PRECIPITATION

- Hardness causing ions are converted from soluble (dissolved) forms to the insoluble (precipitated) forms for later removal by sedimentation or filtration
- As pH increases, the solubility of Ca and Mg decrease
  - Ca & Mg will be oxidized and precipitate out as solids
- Methods:
  - Lime softening
  - Lime-soda ash softening
  - Excess lime treatment
  - Caustic-soda treatment

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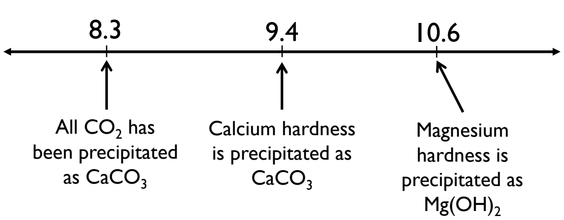
HARDNESS PRECIPITATION

pH Scale



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CHEMICAL REACTIONS

- CO_2 will remove lime
  - Aerate to remove CO_2
  - Add excess lime to compensate for consumption by CO_2

18

LIME SOFTENING

- Used if there is little or no noncarbonate (permanent) hardness
- Types of lime
  - Hydrated lime
    - Slaked lime
    - Calcium hydroxide - $Ca(OH)_2$
  - Quicklime
    - Unslaked lime
    - Calcium oxide - CaO

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LIME-SODA ASH SOFTENING

- Most common used process
- The hardness causing ions are precipitated and removed by conventional processes
- Does not remove all hardness
  - 50 to 85 mg/L remains
- Removes both carbonate and noncarbonate hardness
  - Soda ash converts the noncarbonate hardness to carbonate hardness
  - Lime converts the carbonate hardness to a calcium carbonate precipitate to be removed later

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EXCESS LIME TREATMENT

- If magnesium hardness exceeds 40 mg/L, more lime must be added to reduce it
- pH must be higher than 10.6 to remove magnesium hydroxide
- Recarbonation must be used to reduce the pH of the water before it enters the distribution system

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SPLIT TREATMENT

- Modification of excess lime process
- Only a portion of the water is treated, saving chemical costs
- Water combined after bypass
- Must bypass all processes including coagulation

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CAUSTIC SODA TREATMENT

- Removes carbonate and noncarbonate hardness
  - Converts carbon dioxide (CO_2) and calcium carbonate ($CaCO_3$) to sodium carbonate (soda ash)
- More expensive than other methods
- Increases TDS in finished water
- Produces less sludge
- Chemical is easier to store, feed, and handle

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ION EXCHANGE

- Requires an ion exchange medium, called a resin
  - Releases the nonhardness-causing ion attached to it in favor of the hardness causing ion present in the raw water
- All hardness is removed
- Very corrosive water must be combined with some unsoftened water to stabilize it
- Ion exchange hardness is measured in grains per gallon (gpg)

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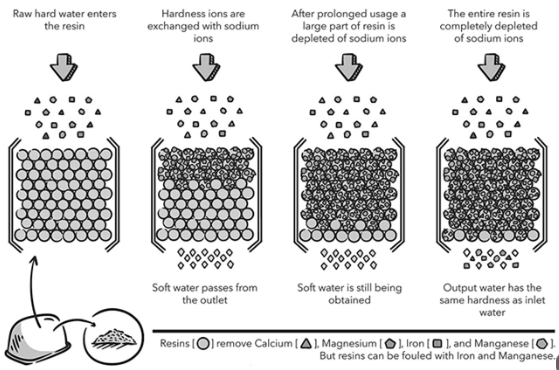
ION EXCHANGE



25

SOFTENING OPERATIONS

- Add softening chemicals
- Conventional treatment or upflow clarifiers can be used
- Precipitates from softening can clog filters
  - May have to backwash more frequently
- Calculate proper dosage of chemicals for type of hardness present by jar test

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OPERATIONS

Operating Problems

- Suspended $CaCO_3$ can pass through to filters
  - Scale formation
  - Clogging
- Must properly stabilize water

Interferences

- Disinfection is less effective at higher pH
  - Requires longer detention time

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RECARBONATION

- Softened water has a pH near 11
  - Saturated with $CaCO_3$
- Recarbonation is the process of adding CO_2 to stabilize water
- pH drops to 8.6
  - Small amount of hardness formed
- Detention time of 15-30 minutes

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SOFTENING

Regulations

- Increased pH from softening increases THM formation potential
- Softened water may affect stabilization
  - Lead and Copper compliance

Record Keeping

- Pounds of chemical used
- Amount of water treated
- Lab test results at various stages
- Sludge production

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Softening Vocabulary

______1. After-precipitation
______2. Calcium Carbonate
______3. Calcium Hardness
______4. Carbonate Hardness
______5. Cation Exchange
______6. Centrate
______7. Decant
______8. Excess-Lime Treatment
______9. Hardness
______10. Ion-Exchange Process
______11. Lime-Soda Ash Method
______12. Loading Rate
______13. Magnesium Hardness
______14. Milk of Lime
______15. Noncarbonate Hardness
______16. Permanent Hardness
______17. Polystyrene Resin
______18. Precipitate
______19. Quicklime
______20. Recarbonation
______21. Regeneration
______22. Resin
______23. Sequestering Agent
______24. Slake
______25. Sludge
______26. Sludge Blowdown
______27. Stabilization
______28. Temporary Hardness
______29. Trihalomethanes

A. Another term for noncarbonate hardness, it does not precipitate when water is boiled.
B. The controlled withdrawal of sludge from a solids-contact basin to maintain the proper level of settled solids in the basin.
C. The addition of water to quicklime, CaO, to form calcium hydroxide, $Ca(OH)_2$, which can then be used in the softening or stabilization process.
D. A characteristic of water, caused primarily by the salts of calcium and magnesium.
E. The continued precipitation of a chemical compound, primarily $CaCO_3$, after leaving the sedimentation or solids-contact basin.
F. The portion of total hardness caused by calcium compounds such as calcium carbonate and calcium sulfate.
G. The most common resin used in the ion exchange process.
H. The reintroduction of carbon dioxide into the water, either during or after lime-soda ash softening, to lower the pH of the water.
I. A process used to remove carbonate and noncarbonate hardness from water.
J. Another term for carbonate hardness, derived from the fact that the hardness causing carbonate compounds precipitate when water is heated.
K. In water treatment, the synthetic, bead-like material used in the ion exchange process.
L. A process used to remove hardness from water that depends upon special materials known as resins. The resins trade no hardness-causing ions for the hardness-causing ions of calcium and magnesium.
M. The water that is separated from sludge and discharged from a centrifuge.
N. The principal hardness- and scale-causing compound in water. $CaCO_3$
O. To draw off the liquid from a basin or tank without stirring up the sediment in the bottom.
P. The lime slurry formed when water is mixed with calcium hydroxide.

Q. Another name for calcium oxide, which is used in water softening and stabilization.
R. A chemical compound such as EDTA or certain polymers that chemically tie up other compounds or ions so that they can't be involved in chemical reactions.
S. The water treatment process intended to reduce the corrosive or scale-forming tendencies of water.
T. (1) A substance separated from a solution or suspension by a chemical reaction. (2) To form such a substance.
U. The portion of total hardness caused by magnesium compounds such as magnesium carbonate or magnesium sulfate.
V. Hardness caused by salts of calcium and magnesium.
W. The accumulated solids separated from water during treatment.
X. Hardness caused primarily by compounds containing carbonate (CO_3), such as calcium carbonate and magnesium carbonate.
Y. A modification of the lime-soda ash method that uses additional lime to remove magnesium compounds.
Z. Ion exchange involving ions that have positive charges, such as calcium and sodium.
AA. The flow rate per unit area at which the water is passed through a filter or ion exchange unit.
BB. The process of reversing the ion exchange softening reaction of ion exchange materials. Hardness ions are removed from the used materials and replaced with nontroublesome ions, thus rendering the materials fit for reuse in the softening process.
CC. A compound formed when natural organic substances from decaying vegetation and soil (such as humic and fulvic acids) react with chlorine.

Softening Review Questions

1. Explain the most important difference in carbonate hardness and noncarbonate hardness.

2. What are the names and formulas of the two principal hardness-causing compounds that settle out during the lime-soda ash process?

3. List some characteristics of hard water.

4. List some characteristics of soft water.

5. How does ion exchange softening process work?

6. In what ways can the softening process affect other treatment plant processes?

7. What is recarbonation and why is it necessary?

Softening Answers

Matching

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

Review Questions

1. Carbonate hardness is caused primarily by the bicarbonate salts of calcium and magnesium, which are calcium bicarbonate and magnesium bicarbonate. Calcium and magnesium combined with carbonate also contribute to carbonate hardness. Noncarbonate hardness is a measure of calcium and magnesium slats other than carbonate and bicarbonate salts.
2. calcium carbonate – $CaCO_3$
   magnesium hydroxide – $Mg(OH)_2$
3. scale forming on cooking utensils, hot water heaters and water fixtures; increase amount of soap needed
4. leaves skin feeling slippery; very corrosive
5. replaces Ca and Mg with Na from resin
6. can increase TDS, may have to aerate to remove CO_2
7. recarbonation is the reintroduction of carbon dioxide into the water, either during or after lime-soda ash softening, to lower the pH of the water; this stabilizes water

Section 6

Ion Exchange

Ion Exchange

1

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Ion Exchange

- Most often used in municipal water treatment to remove unwanted ions
  - Arsenate
  - Nitrate
  - Hardness (calcium and magnesium)
- Common alternative to cold process lime-soda ash softening

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Ion Exchange

- Requires an ion exchange medium called a resin
- Releases the nonhardness-causing ion attached to it in favor of the hardness causing ion present in the raw water
- Process does not alter the pH or alkalinity of the water
- The removal of Ca and the increase of TDS alters the stability of the water

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Ion Exchange

- TDS
  - 1 mg/L of Ca removed and replaced with Na
    - the TDS increases 0.15 mg/L
  - 1 mg/L of Mg removed and replace with Na
    - the TDS increases by 0.88 mg/L
- Hardness is expressed as grains per gallon, or just simply grains
  - 1 grain = 17.12 mg/L
  - 1 grain = 0.142 lb/1000 gal

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Ion Exchange

Softening Facilities

- Basic Components
  - Ion exchange materials (resin)
  - Ion exchange units
  - Salt storage tanks

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Ion Exchange

Resins

- Most are made by styrene and divinylbenzene (DVB)
  - Styrene provides the basic matrix of the resin
  - DVB is used to crosslink the resin
    - provides insolubility and toughness to resin
- Two Types
  - Cation exchangers
  - Anion exchangers

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Ion Exchange Resins

Cation Exchangers

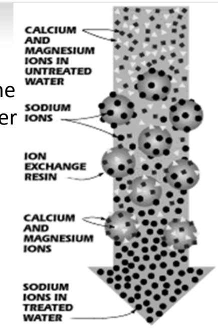
- Positively charged ions that migrate toward the cathode (Ca^+ and Mg^+)
- Used to exchange unwanted positively charged cations with cation species
  - i.e. sodium (Na^+) or hydrogen (H^+)
- Strong-acid cation exchangers work over the entire pH range
- Weak-acid cation exchangers only operate above pH 4

8

Ion Exchange Resins

Cation Exchangers

- Ca and Mg ions are exchanged for Na on the resin to soften the water
  - Ca is calcium
  - Mg is magnesium
  - Na is sodium



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Ion Exchange Resins

Anion Exchangers

- Negatively charged ions that migrate toward anode
  - i.e. nitrate (NO_3) and sulfate(SO_4)
- Used to exchange unwanted anions with anion species
  - i.e. chloride (CL^-) or hydroxide (OH^-)
- Strong-base anion exchangers operate over the entire pH range
- Weak-base anion exchangers do not remove anions above pH 6

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Ion Exchange Units

- Resemble pressure filters
- Tank interior coated with a special lining to prevent corrosion caused by the brines (high salt concentration) used in regenerations
- Upflow and downflow units available

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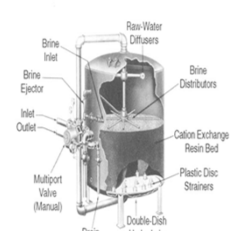
Ion Exchange Units



Courtesy of US Filter/Permutit

FIGURE 12-4 Vertical-downflow ion exchange unit

Components

- Hard-water inlet
- Soft-water outlet
- Wash-water inlet and collector
- Brine inlet and distribution system
- Brine and rinse-water outlet
- Rate-of-flow controllers
- Sampling taps
- Underdrain systems
- Graded Gravel

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Ion Exchange

Regenerant Storage Tanks

- To form brine that is used to regenerate the resin, sodium chloride or potassium chloride are the most common salts used in water softening
- Brine is heavier than water
  - To get the highest concentration brine, you would pump from the bottom of the tank

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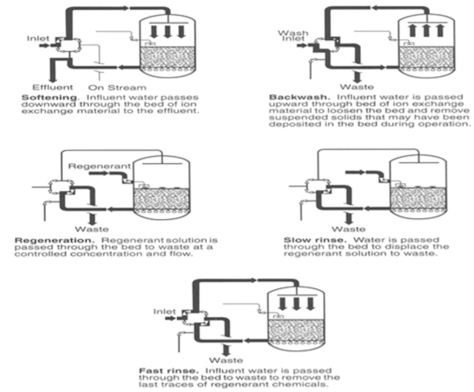
Ion Exchange

Operation of Processes

- Four basic cycles in the water softening ion exchange process:
  - Softening
  - Backwash
  - Regeneration
  - Rinse



Courtesy of Infilco Degremont Inc., Richmond, Va.

FIGURE 12–5 Four cycles in the ion exchange process

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Ion Exchange Cycles

Backwash

- Loosens the resin that has compacted
- Randomly mixes the resin
- Removes any silt, dirt, precipitated iron
- Bed is expanded 50 - 75%
- Typical flow rates are 5-8 gpm/ft^2

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Ion Exchange Cycles

Regeneration

- Requires 5 - 15% of the product water
- Also called *brining*
  - Displaces ions held onto the resin sites
- Follows backwash

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Ion Exchange Cycles

Regeneration

- The resin holds the unwanted ion temporarily, releases it when a regenerant solution is used to restore resin to its original form
- The process of regeneration allows the resin to be reused

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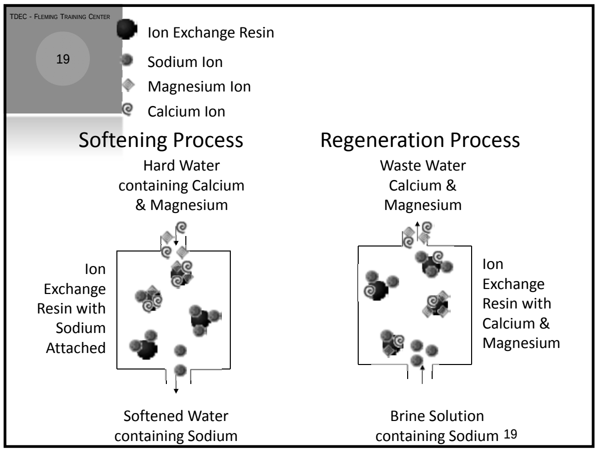
Ion Exchange Cycles

- Regeneration
- The regeneration process using sodium chloride , or salt, as the regenerant involves the following chemical reaction:

$$CaX + 2NaCl \longleftrightarrow CaCl_2 + Na_2X$$

$$MgX + 2NaCl \longleftrightarrow MgCl_2 + Na_2X$$



Ion Exchange Cycles

- Rinse
  - Removes excess regenerant from the resin bed
  - Typically uses raw water
  - Softening operations usually use both a slow and a fast rinse
- Service
  - Operational cycle (softening process, demineralization process or the process of removal of unwanted contaminants)

Regenerant Disposal

- Options evaluated before process chosen
  - Cost of disposal can effect selection of softening process
- Primarily dependent on state pollution control agency
- TDS runs between 35,000 - 45,000 mg/L
  - Can cause pipe corrosion and upset biological processes in wastewater treatment plants

Regenerant Disposal

- If not properly disposed of, negative effects can occur
  - Land application
    - can make unusable for agriculture
  - Discharged to seepage bed
    - can contaminate aquifers

Operating Problems

- Resin deterioration
- Iron fouling
- Turbidity, organic and bacteriological slime fouling
- Removal of arsenic, barium, radium, nitrate and uranium
- Unstable water

Operating Problems

Resin Deterioration

- Designed to last 15-20 years
- Can come under attack by oxidizers
- Deterioration due to
  - Physical degradation to smaller particles
  - Decross-linking and subsequent swelling
  - Loss of breakthrough capacity
  - Loss of acidity of functional groups
  - Poisoning of functional groups
  - Fouling due to precipitation in or on the exchanger surface

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Operating Problems

Iron Fouling

- Uncomplexed soluble iron is cationic in nature and is removed by cation exchangers
- Iron complexed with organic matter is anionic and is not removed by cation exchange
- Iron can form insoluble hydroxides when exposed to air and precipitate on cation exchange resins, which decreases the resins' exchange capacity
- Best solution: remove iron before ion exchange

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Operating Problems

Turbidity, Organic Color and Bacterial-Slime Fouling

- Turbidity and bacterial slimes, measured by HPC (heterotrophic plate count), in raw water will coat the resin, decrease exchange capacity and cause excessive head loss
- Backwashing removes some (becomes tightly held onto the resins)
- Highly colored water, highly turbid water and water with an HPC concentration require pretreatment

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Operating Problems

Removal of As, Ba, & Ra

- Arsenic (As)
  - Exists as arsenite (AsO_3) and arsenate (AsO_4)
  - Soluble forms removed with strong-base anion exchange in chloride form when waters are low in divalent anions, such as sulfate
- Barium (Ba) & Radium (Ra)
  - Found frequently in groundwater
  - Exceed MCL in many wells
  - Removed by strong-acid cation exchangers in the sodium or hydrogen cycle

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Operating Problems

Removal of NO_3 and U

- Nitrate (NO_3)
  - Found in shallow wells in rural areas
    - agricultural contaminant
  - Present in excess of MCL, 10 mg/L
  - Strong-base anion exchange process
    - uses a single bed chloride cycle
- Uranium (U)
  - Cation and anion exchange resins used successfully
  - Strong-base anion exchange in the chloride cycle is better and more cost-effective

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Operating Problems

Unstable Water

- Water softened by the ion exchange process is corrosive as tested by the Langelier saturation index
- To help this, there are 2 options:
  - Blending raw water and treated water
  - Adding chemicals to provide corrosion control

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Record Keeping

- Records kept for tracking performance of the softening process and for ordering chemicals
- Each operator should develop the records required

Section 7

Adsorption

ADSORPTION

Fleming Training Center
TN Department of Environment & Conservation

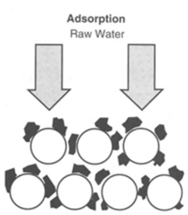
1

OBJECTIVES

- The origin of organic chemicals in groundwater and surface water
- The methods of removing organic chemicals
- The principles of adsorption
- Types of activated carbon
- Operation and safety of activated carbon

2

ADSORPTION



Particles stick to the media and cannot continue downward through the media.

- Adsorption is the process of removing contaminants, usually organic, from water by adhering them onto the surface of an adsorbent, such as activated carbon

3

ORGANICS IN WATER

- Organics causing taste, odor, & color
- Synthetic organics (SOC's) that may cause adverse health effects; some have established MCL's
- Precursors to DBPs
- DBPs that have been formed

4

ORIGIN OF ORGANICS

- "Organic" means containing carbon
- Naturally occurring organics come from soil and vegetation
- Synthetic organics include pesticides, industrial chemicals, oils, etc.

5

ORGANICS IN SURFACE WATER

- Many water systems that use surface sources have bothersome tastes, odors or color in their source water at some time or another
- Precursors for the development of THM's and other DBP's are present in most surface waters

6

ORGANICS IN GROUNDWATER

- Groundwater does not usually contain much organic matter
- Shallow wells, on occasion, have had relatively high levels of humic substances
- Groundwater can become contaminated with SOC's (synthetic organic chemicals) such as pesticides, solvents, etc.
- In a number of locations the concentration has been high enough that the well has been discontinued or special treatment began to remove the SOC's

7

ORGANIC CHEMICAL REMOVAL

- The best place to control organics in drinking water is at the source.
  - Control of watershed
  - Control of algae growth
- Groundwater systems might establish restrictions on land use in the recharge zone or construct barriers to prevent contaminants from flowing toward a well in the aquifer.

8

REMOVAL BY OTHER PROCESSES

- Oxidation
  - chlorine, potassium permanganate, chlorine dioxide or ozone
- Aeration combined with coagulation, flocculation, sedimentation, filtration
- Adsorption
  - activated carbon

9

PRINCIPLE OF ADSORPTION

- Organic contaminants adhere to surface of adsorbent
- Adsorbent must provide very large surface area for contaminant to adhere - porous
- Activated carbon has large surface area and varying pore sizes
  - 1 lb has a surface area of 150 acres
- Carbon is activated by heating to high temp in presence of steam
- Surface area is increased
  - holes and crevices formed for particle attachment

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SOURCE OF ACTIVATED CARBON

- Can be made from a variety of materials - wood, peach pits, coconut shells, coal, peat, petroleum residues; usually comes from coal
- Coal is converted to carbon by heating without oxygen
- Activated by exposure to steam-air mixture
- Crushed and screened to get proper particle size - powder or granule

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POWDERED ACTIVATED CARBON

- Can be fed dry or in a slurry with water; doesn't mix well with water - hydrophobic
- Most commonly used to control tastes & odors
- Cheaper than GAC, can be fed only when needed
- Most common problem is handling
- Apply near mixing facilities - carbon must come in contact with substances to be removed

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DRY FEED SYSTEMS

- If a plant uses PAC only during certain times of the year, dry feed may be best
- Feeder feeds to tank or ejector, carbon is mixed with water to form a thin slurry
- Use only feeder specifically designed for carbon
- Feeder should be capable of operating over wide range of dosages
- Feed rate doesn't have to be precise

SLURRY FEED SYSTEMS

- Systems using PAC continuously can have slurry feed system
- High speed mixer required to form slurry
- After slurry is formed, low speed mixer maintains slurry - requires constant mixing
- Fed from day tank by volumetric feeder

APPLICATION POINT OF PAC

- Contact time should be at least 15 minutes with carbon in suspension before any chlorine is added
- PAC particles lose ability to adsorb if coated with coagulant or other chemicals
- PAC will adsorb chlorine (possibly increasing Cl_2 demand), $KMnO_4$, ozone, chlorine dioxide
- If fed too near filters, may pass through creating black water problems
- Raw intake or flash mix may be best application point if adequate mixing and detention time are available

DETERMINING PAC DOSAGES

- Jar test - for taste & odor removal, use odor test on jar samples
- Use results on plant-scale, monitor raw and finished water with odor test (TON) on each shift, or at least once daily

RECORD KEEPING - PAC

- Keep track of PAC usage for future reference
  - Time of year
  - Effective dose
  - Type of taste or odor problems
  - TON values for raw and finished water

GRANULAR ACTIVATED CARBON

- For continuous removal of organics from groundwater or surface water
- Used as filter media or in contactors
- Higher installation and operating costs
- After installation, requires little maintenance, no handling
- More efficient than PAC at removing SOCs

GAC AS FILTER MEDIA

- Can be installed in place of sand or anthracite in open filters
- Can be added over media
- Acts as adsorbent and filter media
- Life of GAC depends on type and amount of organics being removed
- Coag/floc/sediment process should be optimized to increase bed life
- Proper backwashing is crucial

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GAC AS FILTER MEDIA

- Rapid growth of bacteria can occur due to adsorbed organics - increased chlorine demand
- Recommended that bed be at least 24 inches thick

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GAC CONTACTORS

- Enclosed pressure tanks used after filtration
- More practical for high organic loading
- Can remove DBPs before water enters distribution system
- Can remove SOCs from contaminated groundwater
- Can be used for emergency treatment - temporary units set up
- Bacteria growth may be problem

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REPLACING GAC

- When exhausted, GAC is removed and replaced, not usually recharged
- Reactivation consists of passing the spent carbon through a regeneration furnace, where it is heated to 1500-1700°F (820-930°C), which oxidizes the impurities
- Disposal can be an issue if used to remove radionuclides from groundwater - low level radioactive waste
- Must be backwashed to remove trapped air and small carbon particles (carbon fines)

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APPLICATION POINT OF GAC IN FILTERS

- Contact time - also called the empty bed contact time (EBCT) - volume of GAC media divided by flow rate
- Filtration rate usually about 2 gpm/ft^2, EBCT is around 7.5 - 9 minutes
- Backwashing - try to prevent media loss

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APPLICATION POINT OF GAC IN CONTACTORS

- Tank size designed for proper contact time
- Tanks can be set up in parallel so they aren't exhausted at same time
- Tanks backwashed to remove suspended matter and carbon fines
- Finished water samples analyzed for organic chemicals , indicates when GAC needs to be replaced

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TESTS OF GAC IN FILTERS

- Core samples taken every six months
- Check for carbon loss during backwashing
- Run threshold odor number test and Heterotrophic Plate Count daily

TESTS OF GAC IN CONTACTORS

- Test for organic chemicals in finished water
- Head loss monitored for backwash purposes
- Core samples taken every 3 months
- HPC before and after chlorination

RECORD KEEPING - GAC

- Keep track of amount of water processed, date GAC was replaced
  - Results of organics tests
  - Carbon level loss
  - Dates when media and GAC replaced
  - Results of periodic TON tests
  - Results of raw and finished water organic concentrations

STORAGE

- PAC and GAC should be stored on pallets in clean, dry area with circulation underneath and access aisles for inspection, not over 6 feet high
- Control dust
  - near motors can increase fire hazard
- No smoking in carbon storage area
- Storage room should be fire-proof, with self-closing doors

STORAGE

- Burns like charcoal, no smoke or flame
- Fire difficult to detect and extinguish - use carbon dioxide or foam, not stream of water
- Do not store near gasoline or oils
- Do not store near chlorine (HTH) or potassium permanganate because of spontaneous combustion
- Explosion-proof light fixtures, electrical wiring
- Tanks should be vented, have dust collectors

PAC AND GAC SAFETY

- Use dust masks, gauntlets, aprons
- Wet activated carbon removes oxygen from the air
- When working with GAC tanks, requires circulation of air to prevent O_2 loss; buddy system
- Exposure to skin not dangerous, but difficult to wash off - inhalation may cause respiratory problems

Adsorption Vocabulary

_______1. Activated Alumina
_______2. Activated Carbon
_______3. Activation
_______4. Adhesion
_______5. Adsorbent
_______6. Adsorption
_______7. Arching
_______8. Bed Life
_______9. Carcinogen
_______10. Contactor
_______11. Eductor
_______12. Empty Bed Contact Time
_______13. Granular Activated Carbon (GAC)
_______14. Herbicide
_______15. Humic Substance
_______16. Insecticide
_______17. Nuclei
_______18. Organic Substance
_______19. Pesticide
_______20. Powdered Activated Carbon (PAC)
_______21. Precursor Compound
_______22. Reactivate
_______23. Slurry
_______24. Synthetic Resin
_______25. Total Organic Carbon (TOC)
_______26. Trihalomethane (THM)

A. A thin mixture of water and any insoluble material.
B. The center of atoms, made up of positively charged particles called protons and uncharged neutrons.
C. The time it takes for a bed of adsorbent to lose its adsorptive capacity.
D. A compound, usually synthetic organic, used to stop or retard plant growth.
E. Activated carbon in a granular form, which is used in a bed, much like a conventional filter, to adsorb organic substances from water.
F. Sticking together.
G. A chemical compound that can cause cancer in animals and humans.
H. Any of the organic substances that react with chlorine to form trihalomethanes.
I. Compound formed when natural organic substances from decaying vegetation and soil (such as humic and fulvic acids) react with chlorine.
J. Material resulting from the decay of leaves and other plant matter.
K. Any material, such as activated carbon, used to adsorb substances.
L. The water treatment process used primarily to remove organic contaminants from the water.
M. Activated carbon in a fine powder form.
N. A chemical substance of animal or vegetable origin, having carbon in its molecular structure.
O. The amount of carbon bound in organic compounds in a water sample as determined by a standard laboratory test.
P. A device used to mix a chemical with water by using a constriction to create a low pressure to draw the chemical into the stream of water.
Q. The process of producing a highly porous structure in carbon by exposing the carbon to high temperatures in the presence of steam.
R. The volume of the tank holding an activated carbon bed divided by the flow rate of water.
S. The chemical compound aluminum oxide, which is used to remove fluoride and arsenic from water by adsorption.
T. A compound, usually a synthetic organic substance, used to kill insects.

U. Bead-like material used in the ion exchange process.
V. A condition that occurs when dry chemicals bridge over the opening from the hopper to the dry feeder, clogging the hopper.
W. To remove the adsorbed materials from spent activated carbon and restore the carbon's porous structure so it can be used again.
X. Any substance or chemical used to kill or control troublesome organisms including insects, weeds and bacteria.
Y. A highly adsorptive material used to remove organic substances from the water.
Z. A vertical steel cylindrical pressure vessel used to hold the activated carbon bed.

Adsorption Review Questions

1. Explain the difference between adsorption and absorption.

2. Adsorption is usually used to remove what type of contaminant from drinking water?

3. If you only need to use carbon during certain times of the year, which type (PAC or GAC) would be the best choice?

4. Where in the treatment process are GAC filters generally located?

5. The best application point for powdered activated carbon is usually ____________________.

6. What test is used to analyze the odor of water?

7. List some hazards associated with the storage of activated carbon.

8. PAC is commonly used to remove ____________________________, while GAC is most commonly used to remove ___________________________.

9. Activated carbon adsorbs chemicals easily because of its large ____________________.

10. What is the process of recharging the adsorption capability of granular activated carbon called?

11. If there is a fire in the activated carbon storage area, what should you use to extinguish it?

12. What safety hazard is created by wet activated carbon?

Answers

Vocabulary

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

Review Questions:

1. Absorption – taking in or soaking up a substance into another substance
   Adsorption – adhesion of contaminants onto the surface of an adsorbent, like activated carbon.

2. Organics

3. PAC

4. After filtration (or to replace part of the filter media)

5. Raw intake

6. Threshold Odor Test (TON)

7. Wet activated carbon removes oxygen from air; it is difficult to locate and extinguish a fire involving activated carbon.

8. Taste & odor compounds; synthetic organic chemicals

9. Surface area

10. Reactivation

11. Carbon dioxide

12. Removes O_2 from air

Section 8

Aeration

Aeration

Aeration

- The process of bringing water and air into close contact to remove or modify constituents in the water
- Aeration removes dissolved gases and oxidizes dissolved metals so they don't interfere with other treatment processes
- The efficiency of the aeration process depends on the amount of surface contact that can be achieved between air and water
  - This is controlled primarily by the size of the water drops or air bubbles that provide the contact area

Goals of Aeration

- Removal of gases - CO_2 and H_2S
- Oxidation of metals to form precipitates - Fe and Mn
- Removal of VOCs - benzene and toluene
- Good ventilation is required for proper removal of volatile gases and to prevent buildup of dangerous gases near the aerator

Effects of Aeration

Carbon Dioxide (CO_2)

- Surface water usually contains low CO_2, but groundwater and very deep lakes may contain very high levels
  - Makes water more acidic (lowers pH)
  - Makes iron removal more difficult
    - Increases solubility
  - Reacts with lime
    - Increases softening costs

Effects of Aeration

Hydrogen Sulfide (H_2S)

- Causes rotten-egg odor, alters taste of coffee, tea, & ice cubes
- Causes corrosion
- May cause black precipitate
- Increases chlorine demand
- Easily removed by aeration
- Requires good ventilation

Effects of Aeration

Methane (CH_4)

- Colorless, odorless, tasteless, lighter than air
- Highly flammable and explosive
- Causes garlic taste in water
- Easily removed by aeration
- Requires good ventilation

Effects of Aeration

Volatile Organic Chemicals (VOC)

- VOCs are "manufactured" chemicals found in many groundwater sypplies
- Some are suspected carcinogens
  - Regulated by EPA
- Not as easily removed by aeration

7

Effects of Aeration

Radon

- Radioactive, colorless, odorless gas
- Present in groundwater, not usually in surface water
- Inhalation hazard - released in homes from showers, washing machines, etc
- Easily removed by aeration
- Requires good ventilation

8

Effects of Aeration

Iron and Manganese (Fe & Mn)

- Present in dissolved form in groundwater & stratified reservoirs
- Stains plumbing fixtures & laundry
- Iron easily oxidized in the air above pH 7.5; manganese not easily oxidized by aeration
- Oxidation turns them into soluble form, must then be removed by filtration

9

Effects of Aeration

Tastes and Odors

- Some are easily removed by aeration
- Some require chemical oxidation or adsorption

10

Effects of Aeration

Dissolved Oxygen (DO)

- Added by aeration, removes "flat" taste
- Can increase corrosivity of water
- Amount of DO depends on temperature
  - Colder water holds more DO
- Algae increases level of DO

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Types of Aerators

- Two types:
  - Water-into-air
    - Produce small drops of water that fall through air
  - Air-into-water
    - Mostly used in wastewater

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Water-Into-Air Aerators

Types

- ☐ Cascade
- ☐ Cone
- ☐ Slat and coke tray
- ☐ Draft
- ☐ Spray
- ☐ Packed towers

Water-Into-Air Aerators

Cascade Aerators

- ☐ Series of steps or stacked metal rings
- ☐ Aeration occurs in splash areas
- ☐ Used to oxidize iron and reduce dissolved gases
- ☐ Water introduced at top and moves downward taking in oxygen

Water-Into-Air Aerators

Cascade Aerators

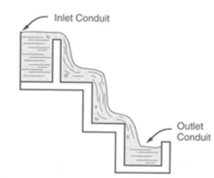
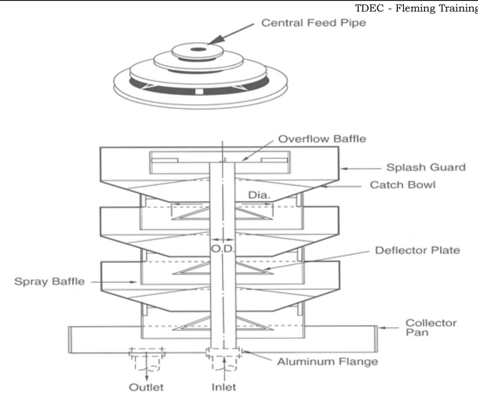


FIGURE 14–2 Stairway-type cascade aerator



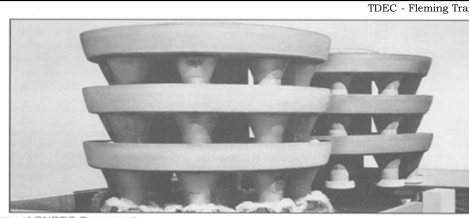
Courtesy of US Filter-General Filter Products

FIGURE 14–3 Ring-type cascade aerator

Water-Into-Air Aerators

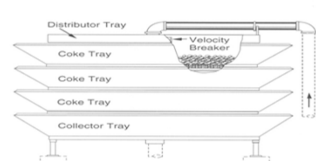
Cone Aerators

- ☐ Similar to ring-type cascade aerators
- ☐ Airs is drawn into stacked pans, mixed with falling water
- ☐ Water cascades downward through cones
- ☐ Usually used to oxidize iron
- ☐ Can reduce dissolved gases



Courtesy of ONDEO Degremont

FIGURE 14–4 Cone aerator



Courtesy of US Filter-General Filter Products, Ames, Iowa

FIGURE 14–5 Schematic of a cone aerator

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Water-Into-Air Aerators

Slat and Coke Tray Aerators

- Consists of 3-5 stacked trays with spaced slats
- Contains media made of coke, rock, ceramic balls, and limestone
- Used to oxidize iron and lower concentration of dissolved gases

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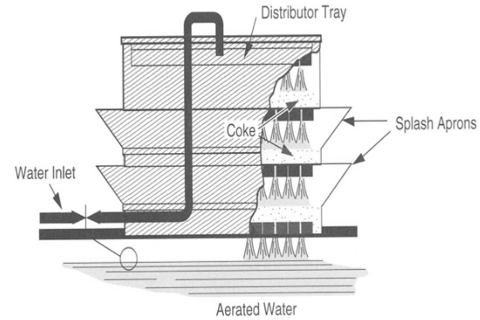

Courtesy of Power Magazine, *McGraw-Hill Inc.*

FIGURE 14–6 Slat-and-coke-tray aerator

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Water-Into-Air Aerators

Spray Aerators

- One or more spray nozzles connected to a pipe manifold
- Moves through manifold under pressure
- Water leaves each nozzle in a fine spray and falls through the surrounding air, creating a fountain effect
- Very successful in oxidizing Fe & Mn
- Increases DO

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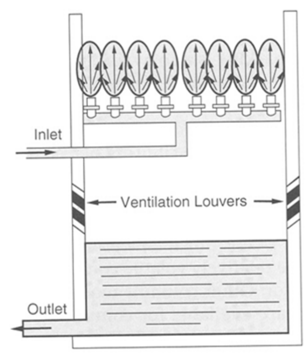

Courtesy of ONDEO Degremont Inc., Richmond, Va.

FIGURE 14–9 Spray tower

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Water-Into-Air Aerators

Packed Tower Aerators

- Air stripper (new development)
- Removes volatile compounds such as VOCs
- Packed towers consist of cylindrical tanks containing a packing material
- Water distributed over the packing at the top
- Air forced in at the bottom
- Large surface area provides for more liquid-gas transfer than other aeration methods
- Minimum air-to-water ratio = 25:1
- Maximum air-to-water ratio = 80:1

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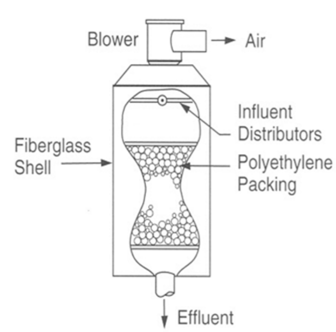
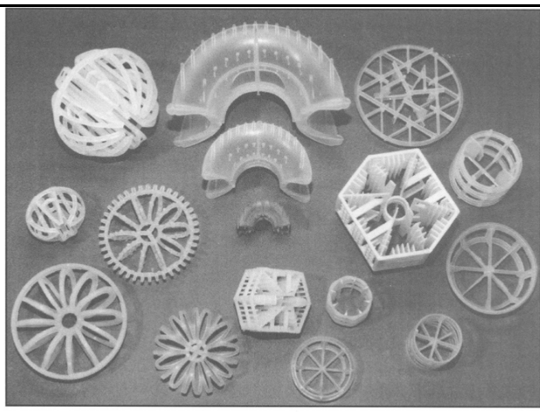


FIGURE 14–12 Cutaway view of interior of a packed tower



Source: US Environmental Protection Agency.

FIGURE 14–11 Typical plastic packing pieces

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Air-Into-Water Aerators

- Diffuser Aerator (air diffuser)
  - Compressed air releases tiny bubbles near bottom of basin
  - Bubbles rise slowly but turbulently through the water, setting up a rolling type mixing pattern
  - Primarily used to increase the DO to prevent tastes and odors

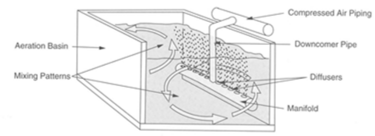

FIGURE 14-14 Diffuser aeration system

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Air-Into-Water Aerators

- Draft Tube Aerator
  - Submersible pump equipped with a draft tube (air intake pipe)
  - Vacuum created at eye of impeller causes air to enter through draft tube and water through the water intake
  - Water & air mixed by impeller and discharged to aeration basin

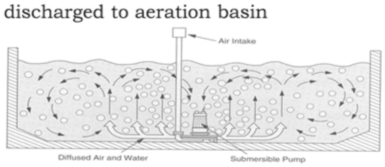

FIGURE 14–17 Draft-tube aerator

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Mechanical Aerators

- Mechanical Aerators
  - Surface aerators (water-into-air type)
    - Draw water into the blade of the aerator and throw the water into the air in tiny droplets
  - Draft-tube surface aerators (water-into-air type)
    - Used to ensure better mixing when surface aerators are installed in deep aeration basins
  - Submerged aerators (air-into-water type)
    - Introduce the air into the water by a submerged air diffuser and a submerged turbine distributes the air
  - Combination mechanical aerators (combo type)
    - Offer the features of both the surface and submerged types

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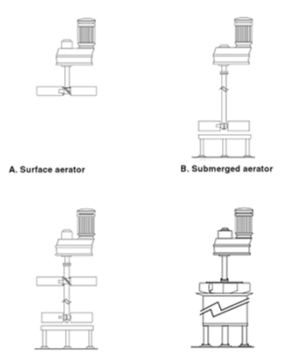

FIGURE 14-18 Four types of mechanical aerators

Courtesy of Philadelphia Mixers Corporation.

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Limitations of Aerators

- Best suited for absorption and release of gases
- Increases DO level which increases corrosivity of water
- Only treatment process that can introduce airborne contaminants into the water
- Taste & odor causing compounds are not volatile enough to respond to aeration
- Efficiency depends on type of taste and odor compound to be removed
- Best suited for treatment of groundwater and removal of CO_2 and H_2S
- Amount of O_2 that will dissolve depends on water temperature
  - Decrease temperature, increase saturation concentration

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Aeration Vocabulary

_______1. Aeration
_______2. Air Binding
_______3. Carbon Dioxide
_______4. Cascade Aerator
_______5. Cone Aerator
_______6. Confined Space
_______7. Corrosion
_______8. Diffuser Aerator
_______9. Dissolved Oxygen
_______10. Draft-Tube Aerator
_______11. Equilibrium
_______12. Hydrogen Sulfide
_______13. Induced Draft Aerator
_______14. Insoluble
_______15. Ionize
_______16. Iron
_______17. Manganese
_______18. Manifold
_______19. Mechanical Aerator
_______20. Methane
_______21. Olfactory Fatigue
_______22. Oxidation
_______23. Permit Required Confined Space
_______24. Photosynthesis
_______25. Positive Draft Aerator
_______26. Pressure Aerator
_______27. Respiration
_______28. Slat & Coke Tray Aerator
_______29. Soluble
_______30. Spray Aerator
_______31. Spray Tower
_______32. Supersaturation
_______33. Taste & Odor
_______34. Turbulence
_______35. Volatile

A. Aerator using a blower mounted on top of a tower to pull air through falling water.
B. The process by which plants, using the chemical chlorophyll, covert the energy of the sun into food energy.
C. Vaporizes easily.
D. Aerator that contains wooden slats and chunks of rock. Good for iron & manganese oxidation.
E. To change or be changed into ions.
F. A toxic gas produced by the anaerobic decomposition of organic matter and by sulfate-reducing bacteria. Has a rotten egg odor.
G. The process of bringing air and water into close contact in order to remove or oxidize unwanted constituents.
H. Aerator that uses perforated pipes or porous plates to inject a gas, such as CO_2 or air, under pressure into water.
I. A pipe with several branches or fittings to allow water or gas to be discharged at several points.
J. (1) The chemical reaction in which the valence of an element increases due to the loss of electrons from that element. (2) The conversion of organic substances to simpler, more stable form by either chemical or biological means.
K. Aerator with a submersible pump equipped with a draft tube. Water and air are mixed by a turbine impeller then discharged into the aeration basin.
L. An abundant element found naturally in the earth; when dissolved in water, it can cause red water problems.
M. A flow of water in which there are constant changes in flow velocity and direction resulting in agitation.

N. Aerator consisting of one or more spray nozzles connected to a pipe manifold. Water under pressure is forced into the air.
O. A colorless, odorless, flammable gas formed by the anaerobic decomposition of organic matter. Can cause a garlic-like taste in water.
P. The point at which your nose no longer can smell a certain odor.
Q. A condition under which water contains very high concentrations of dissolved gas.
R. A condition that occurs in filters when air comes out of solution as a result of pressure decreases and temperature increases. The air clogs the voids between the media grains, causing increased head loss through the filter and shorter filter run.
S. Aerator consisting of a propeller-like mixing blade mounted on the end of a vertical shaft driven by a motor.
T. Not dissolved; solid; will precipitate.
U. Aerator that channels water through cone-shaped nozzles in the bottom of each pan; primarily used to oxidize iron; can be used to partially reduce dissolved gases.
V. An abundant element found naturally in the earth; when dissolved in water, it can cause black stains to plumbing fixtures and laundry.
W. Aerator in which water is sprayed in to air in a pressurized tank, or a stream of air bubbles is diffused directly into a pressurized pipeline.
X. Aerator that uses a series of steps over which water runs.
Y. Housing for a certain aerator that protects the spray from wind-blown losses and can help reduce freezing problems.
Z. Balanced.
AA. Problems associated with dissolved metals and gases in the water usually through customer complaints.
BB. The amount of oxygen gas the water contains.
CC. Will dissolve.
DD. The gradual deterioration or destruction of a substance by chemical action.
EE. (1) Large enough and so configured that employees can bodily enter and perform assigned work and; (2) Has limited or restricted means for entry or exit, and; (3) Is not designed for continuous occupancy.
FF. Aerator using a blower mounted at the bottom of the tower to force air through the falling water.
GG. A common gas in the atmosphere that is very soluble in water. High amounts of this gas in water can cause it to be corrosive due to the acid it forms.
HH. The process by which a living organism takes in oxygen from the air or water, uses it in oxidation, and gives off the products of oxidation, especially carbon dioxide.
II. Confined Space with one or more of the following: (1) Contains or has the potential to contain a hazardous atmosphere; (2) Contains a material that has the potential for engulfing an entrant; (3) Has an internal configuration such that an entrant could be trapped or asphyxiated by inwardly converging walls or by a floor which slopes downward and tapers to a smaller cross-section; or (4) Contains any other recognized serious safety or heath hazard.

AERATION
QUIZ

1. List the two processes involved in aeration.

2. List 6 constituents affected by aeration.

   -
   -
   -
   -
   -
   -

3. List the water quality or operational problems associated with each in question #2.

4. List 2 main methods of aeration.

5. List a problem associated with excessive D.O. concentrations

6. What is the most efficient method for removing H_2S from water?

7. List at least 2 methods for minimizing energy consumption during aeration.

8. List the 3 basic control tests used in the aeration process.

9. Which type of water requires a greater frequency of testing:
   Well water or Surface water

10. There are 2 gases released during aeration that present a danger. List these two gases and their dangers.

11. What are the two methods for dealing with these dangers?

Answers to Aeration Vocabulary:

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

Answers to Review Questions:

1. Removal of gases and VOC's and oxidation of metals.
2. Carbon dioxide, hydrogen sulfide, methane, volatile organic compounds, radon, iron and manganese, tastes and odors
3. <u>Carbon dioxide</u> – makes water more acidic; makes iron removal more difficult; reacts with lime
   <u>Hydrogen sulfide</u> – causes rotten egg odor; alters taste of coffee, tea, ice cubes; causes corrosion; increases chlorine demand; may cause black precipitate
   <u>Methane</u> – causes garlic taste in water; highly flammable and explosive
   <u>VOC's</u> – suspected carcinogen
   <u>Radon</u> – radioactive; inhalation hazard
   <u>Iron and manganese</u> – stains plumbing fixtures and laundry
4. water-into-air and air-into-water (diffusers)
5. corrosive water
6. H_2S is very unstable and is easily removed from water by almost any method of aeration.
7. Operators can minimize power costs by not over aerating, keeping motors and blowers properly maintained and keeping air diffusers clean and free of debris.
8. Dissolved oxygen (DO), pH and temperature
9. Surface water – subject to more frequent change. Temperature, DO, pH, CO_2, and tastes and odors can vary daily.
10. Hydrogen sulfide is a poisonous gas and methane is highly flammable and explosive
11. Sufficient air movement in the vicinity of the aerator so that the gas is carried away.

Section 9

Cross Connections

Cross-Connection Control

Outline

- Case studies of backflow incidents
- Basics of Cross-Connection Control
- Hydraulics
- Definitions
- Backflow Preventers
- Applications

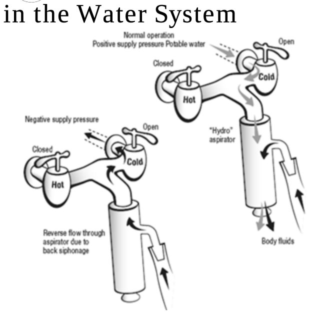
Backflow Case Study

Human Blood in the Water System

Blood observed in drinking fountains at a funeral home

Hydraulic aspirator used to drain body fluids during embalming

Contamination caused by low water pressure while aspirator was in use



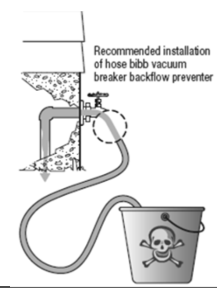
Backflow Case Study

Kool-Aid Laced with Chlordane

Exterminator submerged garden hoses in small buckets while mixing insecticide at the same time a water meter was being installed nearby

During a new water meter installation chlordane was backsiphoned into water lines and became mixed with Kool-Aid

A dozen children and three adults became sick



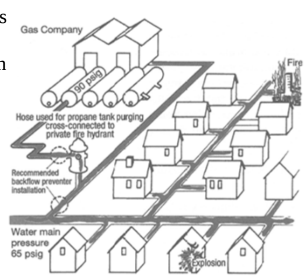
Backflow Case Study

Propane Gas in the Water Mains

Gas company initiated repairs on 30,000 gallon liquid propane tank by flushing with fire hydrant

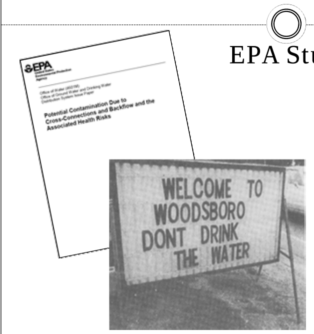
Vapor pressure of propane residual in the tank exceeded water main pressure

Hundreds evacuated, two homes caught fire, water supply contaminated



Backflow Case Study

EPA Study



EPA compiled backflow incident data from 1970 to 2001 and found:

459 incidents resulted in **12,093** illnesses

Backflow incidents can result in property damage, personal injury, and even death

Authority

- Federal
  - Federal Safe Drinking Water Act
- State
  - Tennessee Safe Drinking Water Act
  - Statute
  - Regulation
- Local
  - Ordinance (City) or Policy (Utility)
  - Plumbing Code
  - Cross Connection Control Plan

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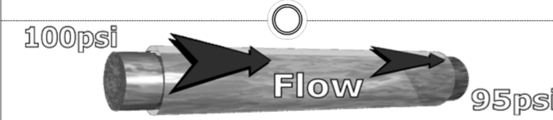
Hydraulics and Pressure



- Water can flow through a pipe in either direction
- The direction of flow will depend on the forces (pressures) acting on the water
- Water pressure naturally tends to equalize
- Therefore, water flows down a gradient from high pressure regions to low pressure regions

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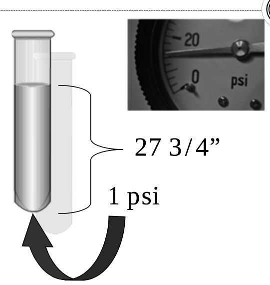
Head Pressure



27 ¾” = 2.31 Feet of Head

- 27 3/4” of water generates a pressure of one pound per square inch (psi)
- The pressure on the bottom of the container is generated by the weight of the water above it

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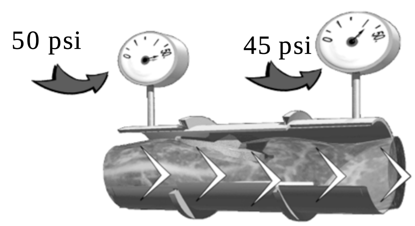
Normal Flow



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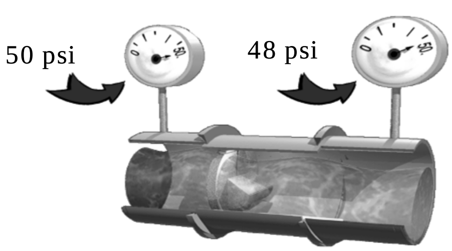
No Flow



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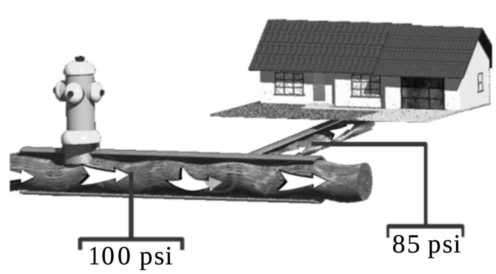
Normal Flow



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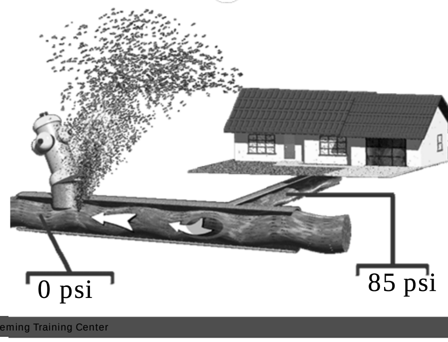
Reverse Flow - Backflow



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Backflow

- The undesirable reversal of flow of water or other substances into the potable water distribution supply
- Occurs due to:
  - Backpressure
  - Backsiphonage

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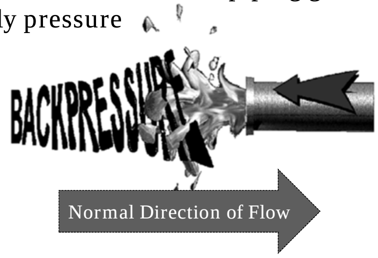
Backpressure

- Pressure in downstream piping greater than supply pressure



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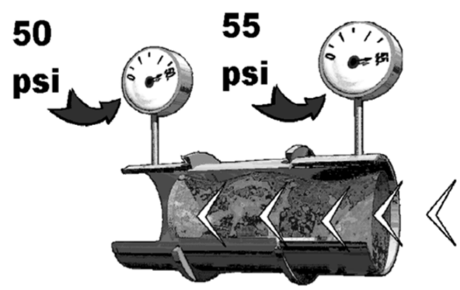
Backpressure



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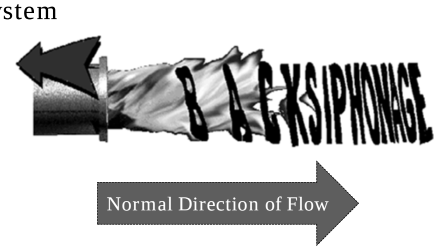
Backsiphonage

- Sub-atmospheric pressure in the water system



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Backsiphonage

What is drawn into the water pipes if backsiphonage occurs?

- As backsiphonage occurs air will be drawn up into the water pipes

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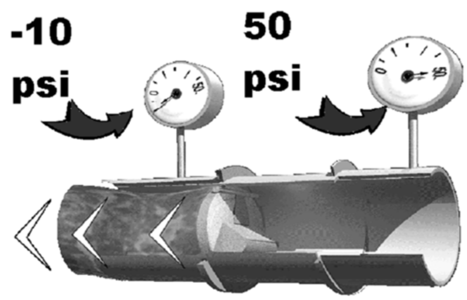
Backsiphonage

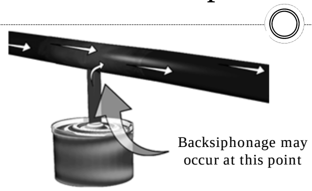
What is drawn into the water pipes if backsiphonage occurs?

- Whatever is in the barrel…

Backsiphonage



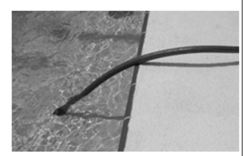
Aspirator Effect



- As water flows through a pipe, the pressure against the walls of the pipe decreases as the speed of the water increases
- If a second pipe is attached there could be a low pressure area created at the point of connection which could siphon water from the attached pipe into the flowing pipe - Backsiphonage

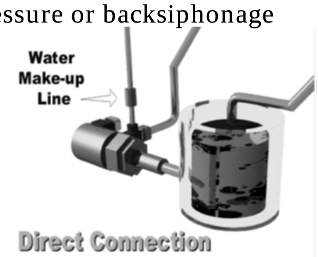
Cross-Connection

- An actual or potential connection between a potable water supply and any non-potable substance or source
- Cross-connection types:
  - Direct
  - Indirect



Direct Cross-Connection

- A direct cross-connection is subject to backpressure or backsiphonage



Indirect Cross-Connection

- An indirect cross-connection is subject to backsiphonage only

Submerged Inlet

Indirect Cross Connection

Submerged Inlet	Low Inlet
	

Low Inlet

Direct Cross Connection?

Degree of Hazard

- Non-Health Hazard
  - Low hazard
  - Will not cause illness or death
  - **Pollutant**

- Health Hazard
  - High hazard
  - Causes illness or death
  - **Contaminant**

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The Backflow Incident

For backflow to occur three conditions must be met:

1. There must be a cross-connection. A passage must exist between the potable water system and another source.
2. A hazard must exist in this other source to which the potable water is connected.
3. The hydraulic condition of either backsiphonage or backpressure must occur.

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Five Means of Preventing Backflow

- Air Gap Separation (AG) **Best Method**
- Reduced Pressure Principle Assembly (RPZ/RPBP/RP) **Best Device**
- Double Check Valve Assembly (DCVA)
- Pressure Vacuum Breaker (PVB)/ Spill-Resistant Vacuum Breaker
- Atmospheric Vacuum Breaker (AVB)

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Air Gap

- An air gap is the vertical separation between the water supply line outlet and the overflow rim of the non-pressurized receiving fixture or tank

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Air Gap

2 X ID,
not <1 inch

- An air gap is the *BEST* method of protection against backflow
- Approved air gap separation must have a vertical unobstructed distance of at least twice the internal diameter of the outlet pipe, but never less than 1 inch

Air Gap Separation Limitations

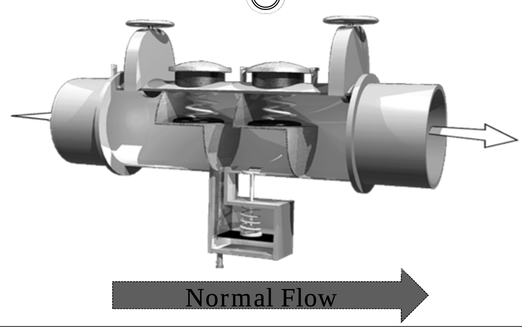
- The air gap is the best method of backflow prevention, but it is easily defeated through modifications or being bypassed
- The air gap separation causes a loss of pressure in the system
- Sanitary control is lost - cannot be installed in an environment containing airborne contamination

Approved Air Gap Separation

Backflow Protection Against:

- Backsiphonage
- Backpressure
- Contaminant (health hazard)
- Pollutant (non-health hazard)

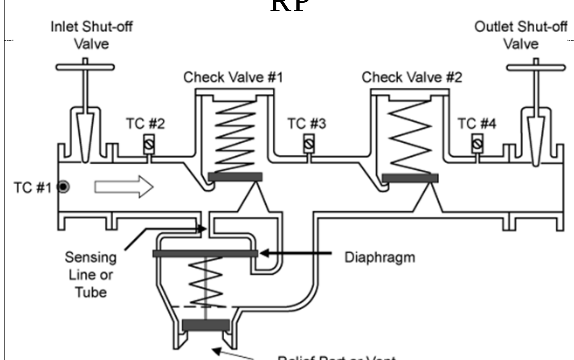
Reduced Pressure Principle Assembly



Reduced Pressure Principle Assembly

- The reduced pressure principle backflow prevention assembly (RP) consists of two independently operating check valves together with a hydraulically operating, mechanically independent, pressure differential relief valve located between the check valves, all located between two resilient seated shutoff valves and four properly located test cocks.
- *BEST* device to protect against backflow

RP



RP

- The two check valves loaded in the closed position mechanically keep the water flowing in one direction through the assembly
- The relief valve assembly is designed to maintain a lower pressure in the zone between the two checks than in the supply side of the unit which hydraulically keeps the water flowing in one direction through the assembly
  - Water always flows from high pressure to low pressure

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RP

Backflow Protection Against:
- Backsiphonage
- Backpressure
- Contaminant (health hazard)
- Pollutant (non-health hazard)

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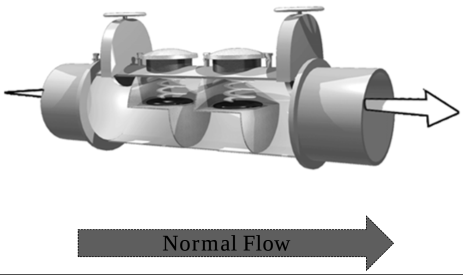
Double Check Valve Assembly (DC)



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Double Check Valve Assembly (DC)

- The double check valve backflow prevention assembly (DC) consists of two independently operating check valves installed between two tightly closing resilient seated shutoff valves and fitted with four properly located test cocks
- Similar to the RP, but has no relief port so it cannot maintain a lower pressure in the zone between the checks and nowhere for the water to go during a backflow incident or failure

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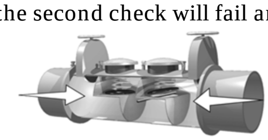
Double Check Valve Assembly (DC)

- Since the water in a DC cannot leave the system during a backflow event or assembly failure then it is a higher risk and therefore cannot be used in a high hazard (contaminant) application
- If one check fails the other will continue to protect, but given enough time the second check will fail and backflow will occur



Second check fouled during backpressure

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Double Check Valve Assembly (DC)

Backflow Protection Against:
- Backsiphonage
- Backpressure
- Pollutant only

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Proper Installation for DC and RP

- Lowest part of the relief valve should be a minimum of 12 inches above either: the ground, the top of the opening of the enclosure wall, or the maximum flood level
  - Whichever is highest, in order to prevent any part of the assembly from becoming submerged
- Maximum 60" above grade to the center line of assembly, if higher then safe permanent access must be provided for testing and servicing

* Tennessee Cross-Connection Control Manual and Design Criteria for Cross-Connection Control Plans, Ordinances, and Policies (2008) – Appendix B

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Proper Installation for DC and RP

- Assemblies should be installed in accordance with manufacturer's installations otherwise it voids the approval for the assembly
- Protected from vandalism and weather (if needed)
- RP requires adequate drainage – ***cannot*** be installed in a pit or meter box
- Must be accessible for testing and repair

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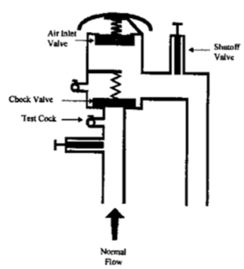
Pressure Vacuum Breaker (PVB)



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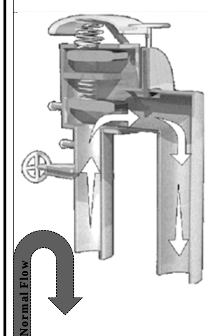
Pressure Vacuum Breaker (PVB)



- The pressure vacuum breaker or spill resistant vacuum breaker consists of an independently operating check valve loaded in the closed position and an independently operating air inlet valve loaded in the open position and located on the discharge side of the check valve, with tightly closing shutoff valves on each side of the check valves, and properly located test cocks for valve testing

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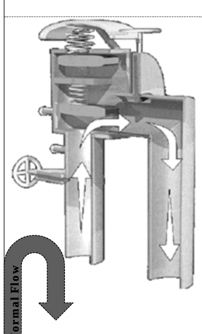
Pressure Vacuum Breaker (PVB)



- Incoming water pressure will compress the spring on the check and flow into the body
- As pressure builds up in the body it will compress the spring on the air valve and close it allowing water to travel downstream

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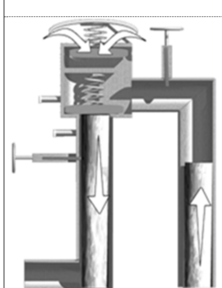
PVB Backsiphonage Condition



- In a backsiphonage condition there is a loss of supply pressure and the check valve is forced closed
- If the body loses pressure the air inlet valve is forced open allowing air into the body of the pressure vacuum breaker and breaking any siphon
- Only to be used to protect against backsiphonage

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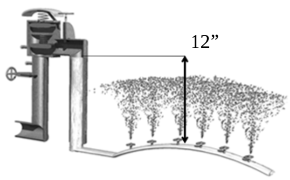
Installation of PVB

- PVB is <u>not</u> designed to protect against backpressure and cannot have any source of backpressure (including head pressure) downstream of the device
- Needs to be installed **<u>12 inches</u>** above the highest point downstream



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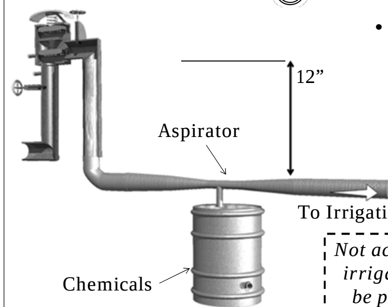
Pressure Vacuum Breaker



- Acceptable installation not subject to backpressure

Not acceptable in TN – all irrigation systems must be protected by an RP

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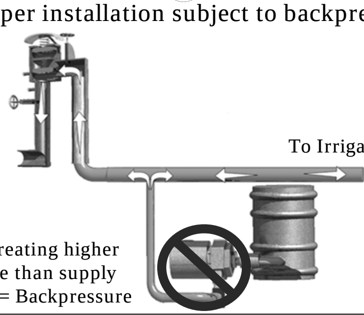
Pressure Vacuum Breaker

- Improper installation subject to backpressure



Pump creating higher pressure than supply pressure = Backpressure

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Pressure Vacuum Breaker

<u>Backflow Protection Against</u>:
- Backsiphonage Only
- Contaminant (health hazard)
- Pollutant (non-health hazard)
- Elevation - at least 12” above downstream piping

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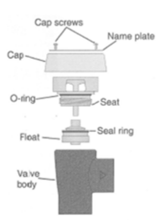
Atmospheric Vacuum Breaker (AVB)



Atmospheric Vacuum Breaker Exploded View

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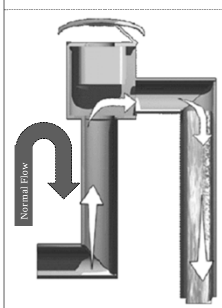
Atmospheric Vacuum Breaker (AVB)



- The atmospheric vacuum breaker is a device designed to prevent backsiphonage. It consists of a body, a single moving float that acts as a check valve when there is no flow and as a air-inlet valve when flow is present, and an air-inlet opening covered by a cap

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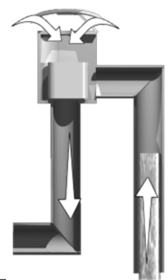
Atmospheric Vacuum Breaker (AVB)

- During a backsiphonage condition the float drops by gravity due to the loss of incoming pressure which automatically opens the air inlet, introducing air into the system to break any siphon that has formed



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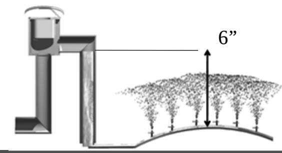
Installation of AVB

- AVB is not designed to protect against backpressure and cannot have any source of backpressure (including head pressure) downstream of the device
- Needs to be installed **6 inches** above the highest point downstream



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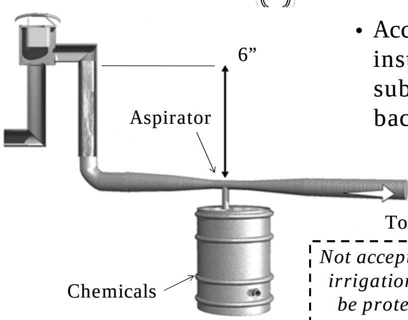
Atmospheric Vacuum Breaker



- Acceptable installation not subject to backpressure

Not acceptable in TN – all irrigation systems must be protected by an RP

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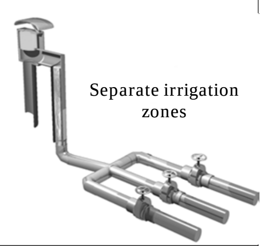
Atmospheric Vacuum Breaker

- Improper installation: downstream shutoff valves
- Shutoff valves downstream of an AVB can cause a continuous use situation
- The float of an AVB subjected to continuous use could begin to adhere to the air inlet and allow backflow



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Atmospheric Vacuum Breaker

Backflow Protection Against:
- Backsiphonage Only
- Contaminant (health hazard)
- Pollutant (non-health hazard)
- Elevation - at least 6”
- Non-Continuous Use

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	Indirect		Direct
	Backsiphonage Only		Backpressure and Backsiphonage
	Continuous Use	Non-Continuous Use	
Health Hazard	Air Gap	Air Gap	Air Gap
	RP	RP	RP
	PVB	PVB	
		AVB	
Non – Health Hazard	Air Gap	Air Gap	Air Gap
	RP	RP	RP
	DC	DC	DC
	PVB	PVB	
		AVB	

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Testing of Assemblies

- Assemblies must be tested when installed, after repair, and at least annually
- Assembly testing must be conducted by certified personnel
- TDEC issues a certification for all assembly testers
- Backflow tester certification courses are offered through the Fleming Training Center

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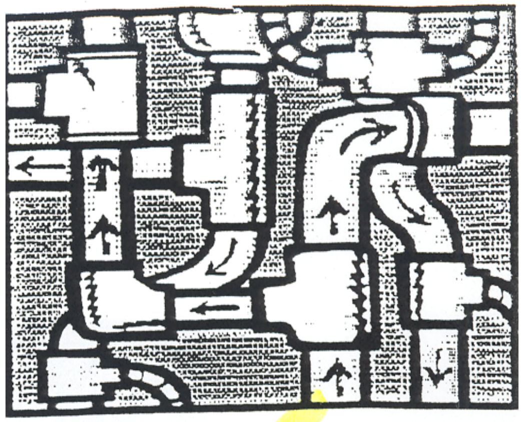


Vocabulary

Absolute Pressure – The total pressure; gauge pressure plus atmospheric pressure. Absolute pressure is generally measured in pounds per square inch (psi).

Air Gap – The unobstructed vertical distance through the free atmosphere between the lowest opening from any pipe or outlet supplying water to a tank, plumbing fixture or other device, and the flood-level rim of the receptacle. This is the most effective method for preventing backflow.

Atmospheric Pressure – The pressure exerted by the weight of the atmosphere (14.7 psi at sea level). As the elevation above sea increases, the atmospheric pressure decreases.

Backflow – The reversed flow of contaminated water, other liquids or gases into the distribution system of a potable water supply.

Backflow Prevention Device (Backflow Preventer) – Any device, method or construction used to prevent the backward flow of liquids into a potable distribution system.

Back Pressure (Superior Pressure) – (1) A condition in which the pressure in a nonpotable system is greater than the pressure in the potable distribution system. Superior pressure will cause nonpotable liquids to flow into the distribution system through unprotected cross connections. (2) A condition in which a substance is forced into a water systems because that substance is under higher pressure than the system pressure.

Backsiphonage – (1) Reversed flow of liquid cause by a partial vacuum in the potable distribution system. (2) A condition in which backflow occurs because the pressure in the distribution system is less than atmospheric pressure.

Bypass – Any arrangement of pipes, plumbing or hoses designed to divert the flow around an installed device through which the flow normally passes.

Chemical – A substance obtained by a chemical process or used for producing a chemical reaction.

Containment (Policy) – To confine potential contamination within the facility where it arises by installing a backflow prevention device at the meter or curbstop.

Contamination – The introduction into water of any substance that degrades the quality of the water, making it unfit for its intended use.

Continuous Pressure – A condition in which upstream pressure is applied continuously (more than 12 hours) to a device or fixture. Continuous pressure can cause mechanical parts within a device to freeze.

Cross Connection – (1) Any arrangement of pipes, fittings or devices that connects a nonpotable system to a potable system. (2) Any physical arrangement whereby a public water system is connected, either directly or indirectly, with any other water supply system, sewer, drain, conduit, pool, storage reservoir, plumbing fixture or other waste or liquid of unknown or unsafe quality.

Cross Connection Control – The use of devices, methods and procedures to prevent contamination of a potable water supply through cross connections.

Degree of Hazard – The danger posed by a particular substance or set of circumstances. Generally, a low degree of hazard is one that does not affect health, but may be aesthetically objectionable. A high degree of hazard is one that could cause serious illness or death.

Direct Connection – Any arrangement of pipes, fixtures or devices connecting a potable water supply directly to a nonpotable source; for example, a boiler feed line.

Distribution System – All pipes, fitting and fixtures used to convey liquid from one point to another.

Double Check-Valve System Assembly – A device consisting of two check valves, test cocks and shutoff valves designed to prevent backflow.

Gauge Pressure – Pounds per square inch (psi) that are registered on a gauge. Gauge pressure measures only the amount of pressure above (or below) atmospheric pressure.

Indirect Connection – Any arrangement of pipes, fixtures or devices that indirectly connects a potable water supply to a nonpotable source; for example, submerged inlet to a tank.

Isolation (policy) – To confine a potential source of contamination to the nonpotable system being served; for example, to install a backflow prevention device on a laboratory faucet.

Liability – Obligated by law.

Negative Pressure – Pressure that is less than atmospheric; negative pressure in a pipe can induce a partial vacuum that can siphon nonpotable liquids into the potable distribution system.

Nonpotable – Any liquid that is not considered safe for human consumption.

Nontoxic – Not poisonous; a substance that will not cause illness or discomfort if consumed.

Physical Disconnection (Separation) – Removal of pipes, fittings or fixtures that connect a potable water supply to a nonpotable system or one of questionable quality.

Plumbing – Any arrangement of pipes, fittings, fixtures or other devices for the purpose of moving liquids from one point to another, generally within a single structure.

Poison – A substance that can kill, injure or impair a living organism.

Pollution – Contamination, generally with man-made waste.

Potable – Water (or other liquids) that are safe for human consumption.

Pressure – The weight (of air, water, etc.) exerted on a surface, generally expressed as pounds per square inch (psi).

Pressure Vacuum Breaker – A device consisting of one or two independently operating, spring-loaded check valves and an independently operating, spring-loaded air-inlet valve designed to prevent backsiphonage.

Reduced-Pressure-Principle or Reduced-Pressure-Zone Device (RP or RPZ) – A mechanical device consisting of two independently operating, spring-loaded check valves with a reduced pressure zone between the checks designed to protect against both backpressure and backsiphonage.

Refusal of Service (Shutoff Policy) – A formal policy adopted by a governing board to enable a utility to refuse or discontinue service where a known hazard exists and corrective measures are not undertaken.

Regulating Agency – Any local, state or federal authority given the power to issue rules or regulations having the force of law for the purpose of providing uniformity in details and procedures.

Relief Valve – A device designed to release air from a pipeline, or introduce air into a line if the internal pressure drops below atmospheric pressure.

Submerged Inlet – An arrangement of pipes, fittings or devices that introduces water into a nonpotable system below the flood-level rim of a receptacle.

Superior Pressure – See backpressure.

Test Cock – An appurtenance on a device or valve used for testing the device.

Toxic – Poisonous; a substance capable of causing injury or death.

Vacuum (Partial Vacuum) – A condition induced by negative (subatmospheric) pressure that causes backsiphonage to occur.

Venturi Principle – As the velocity of water increases, the pressure decreases. The Venturi principle can induce a vacuum in a distribution system.

Waterborne Disease – Any disease that is capable of being transmitted through water.

Water Supplier (Purveyor) – An organization that is engaged in producing and/or distributing potable water for domestic use.

Cross Connection Vocabulary

______1. Air Gap
______2. Atmospheric Vacuum Breaker
______3. Auxiliary Supply
______4. Backflow
______5. Back Pressure
______6. Backsiphonage
______7. Check Valve
______8. Cross Connection
______9. Feed Water
______10. Hose Bibb
______11. Overflow Rim
______12. Pressure Vacuum Breaker
______13. Reduced Pressure Zone Backflow Preventer
______14. RPBP

A. A valve designed to open in the direction of normal flow and close with the reversal of flow.
B. A hydraulic condition, caused by a difference in pressures, in which non-potable water or other fluids flow into a potable water system.
C. Reduced pressure backflow preventer.
D. In plumbing, the unobstructed vertical distance through the free atmosphere between the lowest opening from any pipe or outlet supplying water to a tank, plumbing fixture or other container, and the overflow rim of that container.
E. A backflow condition in which the pressure in the distribution system is less than atmospheric pressure.
F. A faucet to which a hose may be attached.
G. A mechanical device consisting of two independently operating, spring-loaded check valves with a reduced pressure zone between the check valves.
H. Any water source or system, other than potable water supply, that may be available in the building or premises.
I. Water that is added to a commercial or industrial system and subsequently used by the system, such as water that is fed to a boiler to produce steam.
J. A device designed to prevent backsiphonage, consisting of one or two independently operating spring-loaded check valves and an independently operating spring –loaded air-inlet valve.
K. A backflow condition in which a pump, elevated tank, boiler or other means results in a pressure greater than the supply pressure.
L. Any arrangement of pipes, fittings, fixtures or devices that connects a nonpotable water system.
M. The top edge of an open receptacle over which water will flow.
N. A mechanical device consisting of a float check valve and an air-inlet port designed to prevent backsiphonage.

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

Section 10

Pumps

Pumps

Introduction to Water Treatment

1

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

2

Necessity of Pumps

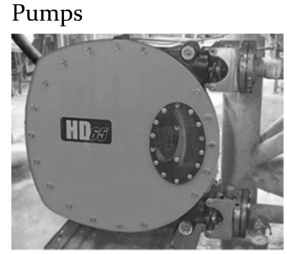
- Pumps are required when gravity cannot supply water with sufficient pressure to all parts of the distribution system
- Pumps account for the largest energy cost for a water supply operation

3

Types of Pumps

- Velocity Pumps

- Positive Displacement Pumps



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Positive Displacement Pumps

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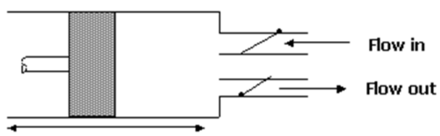
Positive-Displacement Pumps

- Produces constant flow when liquid flows into an expanding cavity on the suction side and then flows out of the discharge side when the cavity collapses
- Used as chemical metering pump
  - Less efficient than centrifugal pumps
  - More precise
- Important Rules:
  - Do not operate against a closed discharge valve
  - When used to pump solids (sludge), precautions to prevent harmful gas accumulation must be taken when suction and discharge valves are closed
  - Never operate when pump is dry or empty
    - Liquid acts a lubricant between moving parts

6

Reciprocating (piston) Pump

- Piston moves back and forth in cylinder
- Liquid enters and leaves through check valves
- Pulsation can be minimized by using multiple cylinders or pulsation dampeners
- Best suited for very high pressures or abrasive/viscous liquids are being pumped



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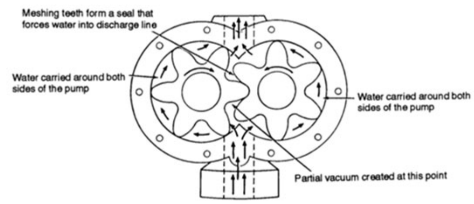
Rotary Pump (AWWA)

- Consists of elements resembling gears that rotate in a close-fitting pump case
- Rotation of these elements draws in and discharges the water



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Peristaltic Pumps

- Can be used for pumping a variety of fluids
- Fluid is contained within a flexible tube fitted inside a circular pump casing.
- A rotor is attached to the external circumference of the rotor and compresses the flexible tube.
- As the rotor turns, the part of tube under compression is pinched closed thus forcing the fluid to be pumped to move through the tube.
- Additionally, as the tube opens to its natural state after the passing of the cam, fluid flow is induced to the pump.
- This process is called peristalsis.

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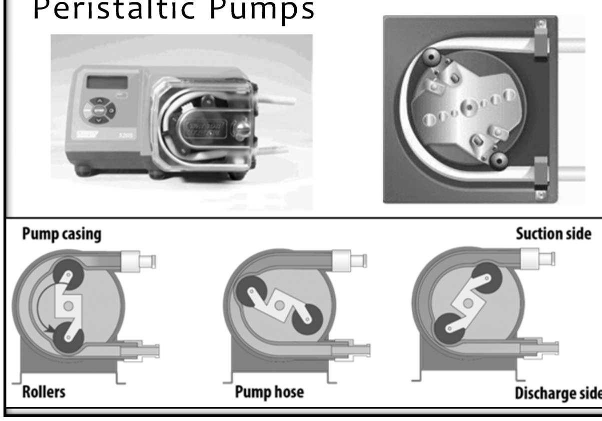
Peristaltic Pumps



Diaphragm Pumps

- When the volume of a chamber of the pump is increased (the diaphragm moving out), the pressure decreases, and fluid is drawn into the chamber.
- When the chamber pressure later increases from decreased volume (the diaphragm moving in), the fluid previously drawn in is forced out.
- Finally, the diaphragm moving out once again draws fluid into the chamber, completing the cycle.
- This action is similar to that of the cylinder in an internal combustion engine.

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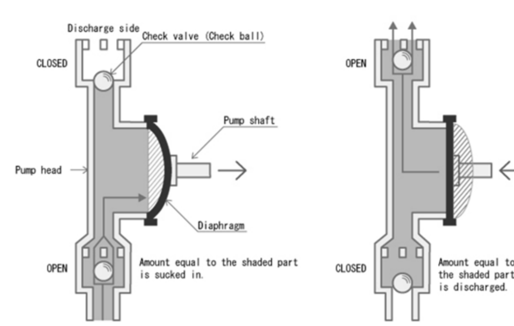
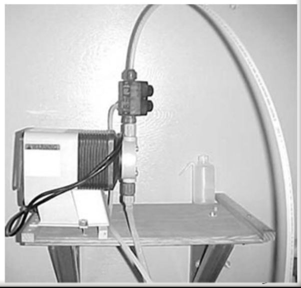
Diaphragm Pump



Diaphragm Pumps



Progressive Cavity Pumps

- Also called Screw-flow Pump
- Consists of screw-shaped rotor with threads
- Threads make contact with walls of stator
- As water is pumped to the spaces between the rotor threads (cavity), the rotor turns and moves the water up and out the discharge
- Recommended for liquids containing higher concentrations of suspended solids

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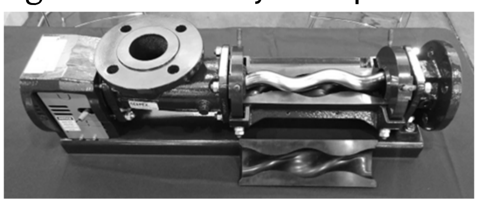
Progressive Cavity Pump



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Velocity Pumps

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Velocity Pumps

- Spinning impeller, or propeller, accelerates water to high velocity in pump casing
- The high-velocity, low-pressure water can be converted to high-pressure, low-velocity water
  - Casing shaped so that water moves through area of increasing cross-section; achieved by:
    - The volute casing shape
    - Specially shaped diffuser vanes or channels such as in the bowls of vertical turbine pumps

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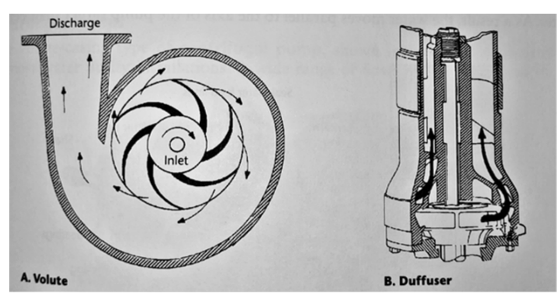
Velocity Pumps



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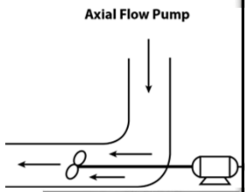
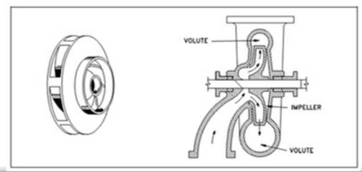
Design Characteristics

- 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
  - Water is pushed upwards by the propeller blades



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
  - Discharge at 90° to the suction
    - Work entirely by centrifugal force and energy transfer



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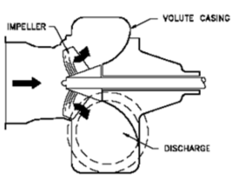
Design Characteristics

- Mixed flow designs
  - Has features of axial and radial flow
  - Works well for water with solids
  - Discharge is at some angle less that 180° from the suction but greater than 90°



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Types of Velocity Pumps

- Centrifugal (volute) Pumps
  - A pump consisting of an impeller on a rotating shaft enclosed by a casing that has suction and discharge connections; spinning impeller throws water outward at high velocity, and the casing shape converts this high velocity to high pressure
- Vertical Turbine Pumps
  - A centrifugal pump, commonly of the multistage diffuser type, in which the pump shaft is mounted vertically
- Centrifugal - Jet Pump Combination
  - Ground-level pump generates high-velocity water that is directed down the well to an ejector

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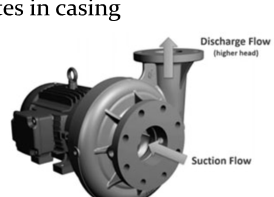
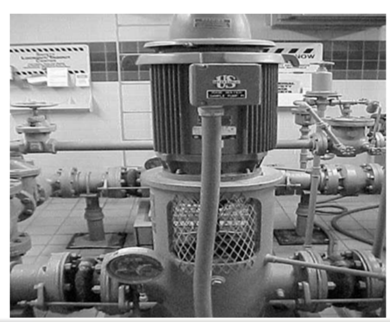
Centrifugal Pumps

- Volute-casing type most commonly used in water utilities
- By varying size, shape, and width of impeller, a wide range of flows and pressures can be achieved
- Radial flow - impeller rotates in casing
- Single or multi-stage



Vertical Turbine Pump



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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

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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

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Jet Pumps

- Part of discharge is used to help run ejector
- Lower efficiency
- Used for small wells

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Centrifugal Pumps

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Centrifugal Pump Operation

- Pump starting and stopping
  - Impeller must be submerged for a pump to start
  - Foot valve holds 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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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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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 pump by feel

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Monitoring Operational Variables

- Vibration
  - Detectors can sense malfunctions causing excess vibration
  - Operators can learn to distinguish between normal and abnormal sounds

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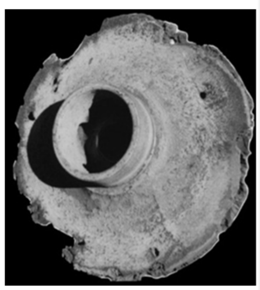
Monitoring Operational Variables

- *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
  - Indicated by pinging sound
    - May sound like marbles in the volute



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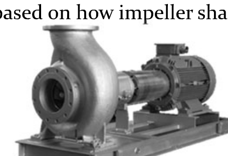
Mechanical Details of Centrifugal Pumps

- 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



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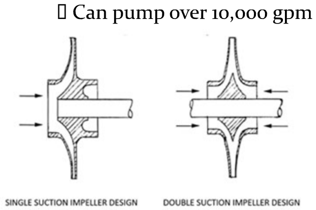
Mechanical Details of Centrifugal Pumps

- Double-suction pumps
  - Water enters from both sides of impeller
  - Commonly called *horizontal split-case*
  - Can pump over 10,000 gpm



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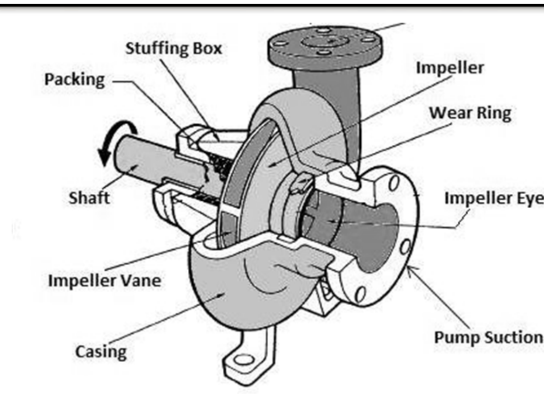

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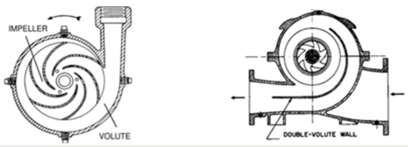
Mechanical Details of Centrifugal Pumps

- 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



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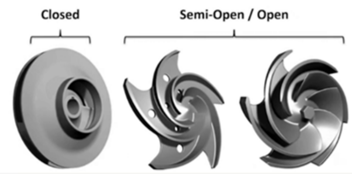
Mechanical Details of Centrifugal Pumps

- Impeller
  - Rotating element in pump
  - Made of bronze or stainless steel
  - Typically, closed design
    - some single-suction have semi open



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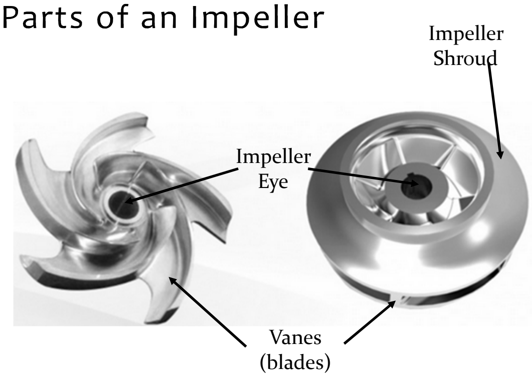
Parts of an Impeller



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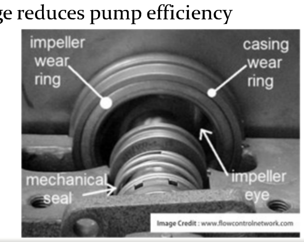
Mechanical Details of Centrifugal Pumps

- 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
- Stuffing box
  - Prevents air entering pump and water leaving
  - Comprised of packing rings, seal cage, and a packing gland

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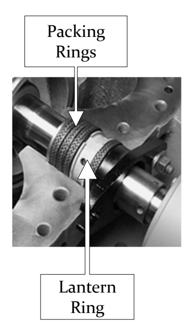
Mechanical Details of Centrifugal Pumps

- Packing rings
  - Seal the space between shaft and casing
  - Has graphite or other lubricating substance
  - Should drip one drop every 2-3 seconds
- Lantern rings (aka seal cage)
  - Perforated ring placed in stuffing box
  - Forms seal around shaft
  - Lubricates packing



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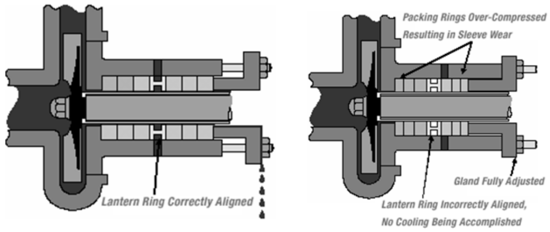
Packing Rings and Lantern Ring



- Proper packing of the stuffing box is vital to the function and lifespan of a pump

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Mechanical Details of Centrifugal Pumps

- 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
  - Maximum operating temperature
    - 160°F (72°C)

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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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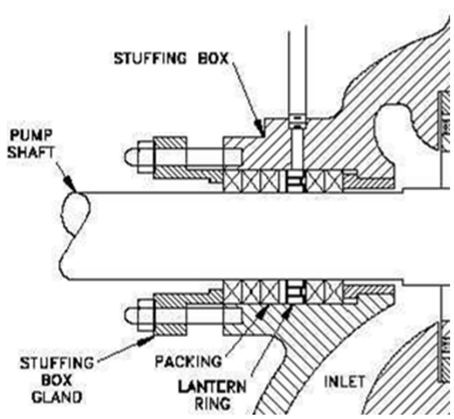

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Mechanical Details of Centrifugal Pumps

- Bearings
  - Antifriction devices for supporting and guiding pump and motor shafts
  - Usually get noisy as they wear out
- Couplings
  - Connect pump and motor shafts
    - Transfer kinetic energy of the motor to the pump
  - 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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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

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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

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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

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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

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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

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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. See also seal cage.

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. Seal Cage – 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. See also lantern ring.

24. Single-Suction Pump – a centrifugal pump in which the water enters from only one side of the impeller. Also called an end-suction pump.

25. 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.

26. Submersible Pump – a vertical-turbine pump with the motor placed below the impellers. The motor is designed to be submersed in water.

27. Suction Lift – the condition existing when the source of water supply is below the centerline of the pump.

28. 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.

29. Vertical Turbine Pump – a centrifugal pump, commonly of the multistage, diffuser type, in which the pump shaft is mounted vertically.

30. Volute – the expanding section of pump casing (in a volute centrifugal pump), which converts velocity head to pressure head.

31. 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.

32. 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 (wearing rings).

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 (72°C).

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. 72°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

Regulations & Design Criteria

Record Category		Time frame required to keep records		Source
Microbiological Records				0400-45-1-.20(1)(a)
Routine distribution		5 years		
Line repair records		5 years		0400-45-1-.17(8)(a)
New line records		5 years		
Bacteriological sampling plan		Keep updated, at least every 3 years		
Chemical Analysis				0400-45-1-.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		0400-45-1-.33(12)
Miscellaneous				
Action regarding violations		3 years		0400-45-1-.20(1)(b)
Certified Letters to Fire Departments regarding Class C hydrants		5 years		0400-45-1-.17(18)
Complaint file		5 years		0400-45-1-.20(1)(h)
Consumer Confidence Reports		3 years		0400-45-1-.35(h)
Cross connection plans and inspection records		5 years		0400-45-1-.20(1)(h)
Daily worksheets, strip charts, shift logs		5 years		0400-45-1-.20(1)(g)
Disinfection Profile		10 years		
Disinfection SOP		Keep updated		
Distribution map		Keep updated, submit copy to DWS every 5 years		0400-45-1-.17(15)
Distribution SOP		Keep updated		
Emergency Operation Plan		Keep updated		0400-45-1-.34(4)(a)
Facility Maintenance Records		5 years		0400-45-1-.20(1)(h)
Flushing records		Survey to survey or 3 years		0400-45-1-.17(10)
MOR's		5 years		
New tap records		Survey to survey or 3 years		0400-45-1-.17(32)
Notice of Construction		Survey to survey or 3 years		
Plant SOP		Keep updated		
Public Notices		3 years		0400-45-1-.20(i)
SDS (Safety Data Sheet)		At least 30 years		29 CFR 1910.1020
Sanitary surveys		10 years		
Storage Tank Inspection Records		5 years		0400-45-1-.17(33), 0400-45-1-.20(1)(h)
Tank maintenance records		Life of tank		0400-45-1-.17(33)
Turbidity analysis: daily worksheets, calibration data and strip charts		5 years		0400-45-1-.20(1)(f)
Variances or Exemptions		5 years		0400-45-1-.20(1)(d)

RULES
OF
THE TENNESSEE DEPARTMENT OF ENVIRONMENT AND CONSERVATION
BOARD OF WATER AND WASTEWATER OPERATOR CERTIFICATION

CHAPTER 0400-49-01
RULES GOVERNING WATER AND WASTEWATER OPERATOR CERTIFICATION

TABLE OF CONTENTS

0400-49-01-.01 APPLICATION FOR CERTIFICATE.

(1) Application for certification by examination.

(a) A separate application for each certification shall be made on an original form approved by the Board for that purpose and available upon request from the Secretary of the Board.

(b) An application for certification must be submitted to the Secretary of the Board and include the following items:

1. A sworn application signed by the applicant.

2. Payment of a non-refundable $100 fee for each application for examination.

3. A copy of any verifying document in support of an application must be submitted with the application unless the applicant has previously provided such documentation to the Secretary of the Board. This includes, but is not limited to, proof of high school education or equivalent of the applicant. College transcripts, if needed to document experience credit, must be submitted directly from the college and/or university to the Secretary to the Board. Credit for enrollment in special training courses and programs will only be granted to an applicant upon verification that he/she satisfactorily completed all course or program requirements. If training credit is requested, a copy of a course attendance card, a class roster, or a certificate of completion must be submitted to the Secretary. Verification of work experience must be provided in a written document signed by a certified operator of a similar or higher classification, familiar with the applicant's work experience. However, if no such person is available, it may be documented by a person in authority with the system. The Board may exempt applicants from the verification of work experience requirement where there are unusual circumstances.

(c) A complete application must be received by the Secretary sixty (60) days or more in advance of the scheduled examination date for consideration. Applications received

(Rule 0400-49-01-.03, continued)

1. Application fee for a Cross Connection Control Basic Test (Department employees who assist with cross connection control training or testing are exempt)…..............................…..............................…................................... $60

2. Application fee for Cross Connection Control Renewal Test (Department employees who assist with cross connection control training or testing are exempt)....................... .... $60

(b) Application fees are not refundable or transferable.

(c) The application for testing conducted by the Department must be received a minimum of thirty (30) days in advance of the test he/she wishes to take, however, applications from private institutions may be received the day the test materials are submitted to the Fleming Training Center.

(d) Prior to sitting for a test, an applicant must present proof of completion of training accepted by the Department for the appropriate test. Basic training may be accepted by the Department if it has a minimum class length of 480 minutes (300 minutes minimum in classroom), including but not limited to the following topics: hydraulic and backflow principles, theory of backflow and cross connection, codes and regulations of a cross connection control program, responsibilities and actions in a cross connection control program and mechanical equipment for cross connection control. Acceptable training must also provide a minimum of one working practice station and test kit for each three students. Renewal training may be accepted by the Department if it has a minimum class length of 300 minutes (180 minutes minimum in classroom) including but not limited to the following topics: hydraulic and backflow principles, theory of backflow and cross connection, codes and regulations of a cross connection control program, responsibilities and actions in a cross connection control program and mechanical equipment for cross connection control. Acceptable training must also provide a minimum of one working station and test kit for each three students.

(e) An applicant must take the test within twelve (12) months of receipt of the training certificate.

Authority: *T.C.A. §§ 4-5-201, et seq.; 68-203-101, et seq.; and 68-221-901, et seq.* ***Administrative History:*** *Original rule filed May 21, 2014; effective August 19, 2014. Rule renumbered from 1200-05-03. Amendments filed January 18, 2017; effective April 18, 2017. Amendments filed April 12, 2021; effective July 11, 2021.*

0400-49-01-.04 GENERAL.

(1) Certification under T.C.A. §§ 68-221-901 et seq., being the “Water and Wastewater Operator Certification Act,” is available to any operator of a water treatment plant, a wastewater treatment plant, a water distribution system, or a wastewater collection system who meets the minimum qualifications of a given classification.

(2) Each person in direct charge at a water treatment plant, a wastewater treatment plant, a water distribution system, or a wastewater collection system shall hold a certificate in a grade equal to or higher than the grade of the treatment plant, distribution system, or collection system he/she operates. The grade of a facility will be established by the criteria set forth in this chapter of rules.

(Rule 0400-49-01-.04, continued)

(3) All operating personnel making process control/system integrity decisions about water quality or quantity that affect public health must be certified. A designated certified operator must be available for each operating shift.

(4) Each water supply system and wastewater system required to have a certified operator shall, no later than the first day of August annually, inform the Board, through its designated agent, the Division of Water Resources, in writing of the name of each person who is a certified operator in direct charge of any water treatment plant, wastewater treatment plant, water distribution system or wastewater collection system it operates. A system shall notify the Division of Water Resources in writing within thirty (30) days of its loss of the services of a certified operator in direct charge.

(5) A certified operator shall be responsible for keeping the Board Secretary informed of his/her current address.

Authority: *T.C.A. §§ 4-5-201, et seq. and 68-221-901, et seq.* ***Administrative History:*** *Original rule filed May 21, 2014; effective August 19, 2014. Rule renumbered from 1200-05-03.*

0400-49-01-.05 DEFINITIONS.

(1) “Available” means that a certified operator must be on site or able to be contacted as needed to initiate the appropriate action in a timely manner, based on system size, complexity and the quality of either the source water or the receiving stream.

(2) “Board” means the board of certification as described in T.C.A. § 68-221-905.

(3) “Commissioner” and “Department” mean the Commissioner of the Tennessee Department of Environment and Conservation or his/her duly authorized representative.

(4) “Operating shift” is that period of time during which operator decisions that affect public health are necessary for proper operation of the system.

(5) “Person in direct charge” as used in these rules means the person or persons expressly designated to be in direct charge and so named in writing to the Board’s authorized representative by each water supply system and wastewater system, whose decisions and directions to system personnel control the manipulation of equipment and thereby determine the quality and quantity of the water supplied by a water treatment plant or a water distribution system, or the quality of the effluent from a wastewater treatment plant or the integrity of a wastewater collection system.

(6) “Process control/system integrity decisions” means decisions regarding the manipulation of equipment, chemicals or processes that determine the quality and quantity of the water supplied by a water treatment plant or a water distribution system, or the quality of the effluent from a wastewater treatment plant or the integrity of a wastewater collection system.

(7) “Written examination” means an examination taken in either written or electronic format.

Authority: *T.C.A. §§ 4-5-201, et seq. and 68-221-901, et seq.* ***Administrative History:*** *Original rule filed May 21, 2014; effective August 19, 2014. Rule renumbered from 1200-05-03. Amendments filed April 12, 2021; effective July 11, 2021.*

(Rule 0400-49-01-.09, continued)

COLLECTION SYSTEM OPERATORS

Classification	Experience		Maximum Training or College Classwork Substitution	Maximum Related Work Substitution
	Experience needed with:	HS Education		
Grade II	Gained at a Collection I or II System	12 Months	3 Months	
Grade I	Gained at a Collection I or II System	12 Months	3 Months	

***Authority:** T.C.A. §§ 4-5-201, et seq. and 68-221-901, et seq. **Administrative History:** Original rule filed May 21, 2014; effective August 19, 2014. Rule renumbered from 1200-05-03.*

0400-49-01-.10 CONTINUING EDUCATION.

(1) Completion of Continuing Education Requirements. At least once during every continuing education period each certified operator shall satisfactorily complete the required number of continuing education hours approved by the Board for the particular type of certificate he/she holds.

(2) Continuing Education Period. The continuing education period is three calendar years and shall begin either with the date the certified operator obtained his/her certificate or the date the certified operator last satisfactorily completed the required number of continuing education hours and shall end at the conclusion of the annual continuing education term three calendar years thereafter. An annual continuing education term shall begin each year on October 1 and shall end on September 30 of the following year.

(3) Failure to Complete Continuing Education Requirements. The failure of an operator to satisfactorily complete the required number of continuing education hours approved by the Board Secretary during his/her continuing education period shall be grounds for the denial of his/her application for the renewal of his/her certificate. An operator that fails to satisfactorily complete the required number of continuing education hours during his/her continuing education period due to extenuating circumstances may make a written request to the Board for an extension of time to do so. All requests by an operator for an extension of time to meet the continuing education requirement must be made in writing to the Board either within two months of the elapsed continuing education period or by the date of return of the operator to active employment, whichever is later. All such requests must be accompanied by complete supporting documentation of the circumstances causing the failure to meet the continuing education requirement.

(4) Notification of Satisfactory Completion. An operator shall notify the Board Secretary upon his/her satisfactory completion of the continuing education requirement by furnishing appropriate documentation of course completion. Notification by the operator is not necessary in those cases where an agency notifies the Board Secretary of such activity.

(5) A certified operator shall only receive credit for a continuing education course that is completed in its entirety. A certified operator attending the same continuing education course more than once in two consecutive continuing education periods shall only receive credit for the operator's first attendance.

***Authority:** T.C.A. §§ 4-5-201, et seq. and 68-221-901, et seq. **Administrative History:** Original rule filed May 21, 2014; effective August 19, 2014. Rule renumbered from 1200-05-03. Amendments filed April 12, 2021; effective July 11, 2021.*

0400-49-01-.11 SUMMARY SUSPENSION AND REVOCATION OF CERTIFICATE.

(1) An operator's certificate may be revoked when:

(a) In accordance with paragraph (2) of this rule, an operator has not used reasonable care, judgment, or the application of his/her knowledge in the performance of his/her duties as a certified operator, or

(b) In accordance with paragraph (3) of this rule, an operator is incompetent to perform those duties properly; or

(c) In accordance with paragraph (4) of this rule, an operator has practiced fraud or deception.

(2) An operator shall be deemed to have not used reasonable care, judgment, or the application of his/her knowledge in the performance of his/her duties if he/she does not comply with the laws, rules, permit requirements, or orders of any governmental agency or court which govern the water supply system or the wastewater system he/she operates. Such acts of noncompliance include but are not limited to the following:

(a) The intentional or the negligent failure by the operator or persons under his/her supervision to act that results in a water supply system facility or a wastewater system facility not operating in the manner in which it is capable of being operated for the performance of its designed function.

(b) The intentional or the negligent failure by the operator or persons under his/her supervision to comply with the monitoring, sampling, analysis, or reporting requirements for a water supply system facility or a wastewater system facility.

(c) The intentional or the negligent unlawful discharge of wastes from a water supply system facility or a wastewater system facility.

(d) The intentional or the negligent failure by the operator or persons under his/her supervision to notify the Department of conditions: which may affect the quantity or quality of water being supplied to the customers of a water supply system; which cause the pollution of the waters of the State of Tennessee; or, which are violative of a standard of water quality promulgated by any governmental agency.

(3) An operator shall be deemed to be incompetent to perform his/her duties properly when he/she does not possess the basic skills and knowledge necessary to operate a water supply system facility or a wastewater system facility including laboratory functions or if he/she fails to have a system of verification and oversight of employees under his/her charge. Incompetency shall be determined by examining the technical skills of the operator in operating the type of facility of which he/she is in direct charge.

(4) An operator shall be deemed to have practiced fraud or deception as follows:

(a) Obtained his/her certificate through fraud, deceit, or the submission of inaccurate data regarding his/her qualifications upon his/her application for a certificate.;

(b) Has practiced fraud or deception during the performance of his/her duties as a certified operator; or

(c) Has prepared and/or signed reports of laboratory analysis results for the system that:

(Rule 0400-49-01-.11, continued)

1. Contain inaccurate data and are known or should be known by the operator to be false; or,

2. Contain inaccurate data because the operator has not used reasonable care, judgment, or the application of his/her knowledge either in the performance of the laboratory analysis or in the preparation of the laboratory analytical reports.

(5) Revocation

(a) The Commissioner may initiate the process to revoke a certificate when he/she believes an operator has engaged in any of the activities set forth in paragraph (1) of this rule.

(b) The Commissioner shall give notice by mail to the affected operator of facts or conduct that warrants revocation of the certificate and give the affected operator an opportunity to show compliance with these rules by conducting an informal hearing as provided in T.C.A. § 4-5-320(c).

(c) After the T.C.A. § 4-5-320(c) informal hearing, if the Commissioner determines that the affected operator has failed to demonstrate compliance, the Commissioner shall issue a notice of hearing for revocation and include a recommendation to the Board to revoke and reinstate or not to reinstate the certificate. Any recommendation of reinstatement of the certificate shall include terms for such reinstatement.

(d) The notice of hearing for revocation shall contain the information required by part 1. of this subparagraph and be served in accordance with part 2. of this subparagraph.

1. The notice shall include:

(i) A statement of the time, place, nature of the hearing, and the right to be represented by counsel;

(ii) A statement of the legal authority and jurisdiction under which the hearing is to be held, including a reference to the particular sections of the statute and rules involved; and

(iii) A short and plain statement of the facts or conduct that warrant a revocation. (If the Commissioner is unable to state the matters in detail at the time the notice is served, the initial notice may be limited to a statement of the issues involved. Thereafter, upon timely, written application a more definite and detailed statement shall be furnished ten (10) days prior to the time set for the hearing.)

2. A copy of the notice of hearing shall be:

(i) Served upon the operator no later than thirty (30) days prior to the hearing date; and

(ii) Served by personal service, return receipt mail or equivalent carrier with a return receipt,

A person making personal service on the operator affected shall return a statement indicating the time and place of service, and a return receipt must be signed by the operator affected. However, if the affected operator evades or attempts to evade service, service may be made by leaving the notice or a copy of the notice at the affected operator's dwelling house or usual place of abode with some person of suitable age and discretion residing therein, whose name shall appear on the proof of service or return receipt card. Service may also be made by delivering the notice or copy to an agent authorized by appointment or by law to receive service on behalf of the affected operator, or by any other method allowed by law in judicial proceedings.

(6) Summary Suspension and Revocation

(a) The Commissioner may initiate the process of summary suspension and revocation of the certificate when the Commissioner believes that an emergency action is needed to protect the public health, safety or welfare.

(b) The Commissioner shall give a notice to the affected operator by any reasonable means and shall inform the affected operator of the intended action, the acts or conduct that warrants summary suspension and revocation of the certificate and hold an informal hearing, as provided in T.C.A. § 4-5-320(d), to give the operator an opportunity to address the issue of whether there is an emergency.

(c) The Commissioner shall appoint a hearing officer to conduct this T.C.A. § 4-5-320(d) hearing and the hearing shall be recorded and transcribed.

(d) After the informal hearing as provided in T.C.A. § 4-5-320(d), if the Commissioner determines that an emergency action is warranted, the Commissioner shall issue an Order of Summary Suspension and a notice of hearing for revocation and include a recommendation to the Board to reinstate or not to reinstate the certificate. Any recommendation of reinstatement of the certificate shall include terms for such reinstatement.

(e) The Order of Summary Suspension and the notice for revocation shall contain the information required by part (5)(d)1. of this rule and be served in accordance with part (5)(d)2. of this rule.

(f) When the Commissioner has issued an Order of Summary Suspension and Notice of Revocation, the Board shall conduct its revocation hearing and render a decision within ninety (90) days of the operator's summary suspension. In the event the Board does not render its decision within ninety (90) days of the operator's summary suspension, the Order of Summary Suspension shall expire and no longer be in force or effect. However, the Commissioner may reissue an Order of Summary Suspension in accordance with this paragraph, for a period not to exceed ninety (90) days.

(7) The revocation hearing before the Board shall be held in accordance with T.C.A. §§ 4-5-301 et seq. and Rule Chapter 1360-04-01 Uniform Rules of Procedure for Hearing Contested Cases Before State Administrative Agencies.

(8) The Board may revoke the certificate of an operator when it is found that the operator has practiced fraud or deception; that reasonable care, judgment or the application of such operator's knowledge was not used in performance of such operator's duties; or that the operator is incompetent to properly perform such operator's duties. If the certificate is revoked and is to be reinstated, the Board shall determine the timing, terms and conditions for reinstatement.

(9) An operator who receives an order of the Board for the revocation of his/her certificate may appeal the order to the Chancery Court of Davidson County within sixty (60) days.

(Rule 0400-49-01-.11, continued)

(10) An operator whose certificate is revoked for failure to use reasonable care, judgment or the application of operator knowledge in performing the operator's duties or for incompetency shall be ineligible to again apply for certification as an operator for a minimum of one (1) year. An operator whose certificate is revoked for practicing fraud or deception, willfully violating regulations or permit conditions, or falsifying records and reports shall be ineligible to again apply for certification as an operator for a minimum of five years. When an operator whose certificate has been revoked has applied for a certificate after the minimum time has passed, the Board shall determine whether the operator has taken appropriate action to address the circumstances that were the cause of the revocation. The Board may request records and review his/her experience, education, training and past performance. The Board may request the former operator's presence at a meeting of the Board and interview him/her to assess the potential of future violations. After the reviews, the Board shall decide to accept or refuse the application.

Authority: *T.C.A. §§ 4-5-201, et seq. and 68-221-901, et seq.* ***Administrative History:*** *Original rule filed May 21, 2014; effective August 19, 2014. Rule renumbered from 1200-05-03.*

0400-49-01-.12 CIVIL PENALTIES.

(1) The Commissioner may assess the civil penalty authorized by law against a municipality, utility district, corporation, or any person operating a water supply system or a wastewater system if the competency of the person in direct charge of a system facility has not first been certified in accordance with these rules.

(2) A certified operator may be assessed the civil penalty authorized by law for the same acts and omissions that would constitute grounds for the revocation of his/her certificate by the Board.

(3) Prior to issuing an order that assess a civil penalty, in accordance with paragraphs (1) and (2) of this rule the Commissioner may hold a show cause meeting with the person or entity to whom the order is proposed to be issued.

Authority: *T.C.A. §§ 4-5-201, et seq. and 68-221-901, et seq.* ***Administrative History:*** *Original rule filed May 21, 2014; effective August 19, 2014. Rule renumbered from 1200-05-03.*

RULES
OF
TENNESSEE DEPARTMENT OF ENVIRONMENT AND CONSERVATION

DIVISION OF WATER RESOURCES

CHAPTER 0400-45-01
PUBLIC WATER SYSTEMS

TABLE OF CONTENTS

0400-45-01-.01 AUTHORITY.

(1) These rules and regulations are issued under the authority of the Tennessee Safe Drinking Water Act of 1983, T.C.A. §§ 68-221-701 et seq.

(2) The Division of Water Resources 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 filed August 1, 2012; effective October 30, 2012. Rule was previously numbered 1200-05-01. Amendments filed November 19, 2018; effective February 17, 2019.*

0400-45-01-.02 PURPOSE.

(1) The purpose of these rules and regulations is to provide guidelines for the interpretation of T.C.A. §§ 68-221-701 et seq. and to set out the procedures to be followed by the Department in carrying out the Department'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

(Rule 0400-45-01-.02, continued)

applicable maximum contaminant levels or treatment technique requirements; in 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 Environment and Conservation 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. and 68-221-701, et seq.* ***Administrative History:*** *Original rule filed August 1, 2012; effective October 30, 2012. Rule was previously numbered 1200-05-01.*

0400-45-01-.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. §§ 4-5-201, et seq. and 68-221-701, et seq.* ***Administrative History:*** *Original rule filed August 1, 2012; effective October 30, 2012. Rule was previously numbered 1200-05-01.*

0400-45-01-.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 0400-45-01-.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) “Clean compliance history” is, for the purposes of Rule 0400-45-01-.41, a record of no MCL violations under paragraph (4) of Rule 0400-45-01-.06; no monitoring violations under Rule 0400-45-01-.07 or Rule 0400-45-01-.41; and no coliform treatment technique trigger exceedances or treatment technique violations under Rule 0400-45-01-.41.

(9) “Coagulation” means a process using coagulant chemicals and mixing by which colloidal and suspended materials are destabilized and agglomerated into flocs.

(10) “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.

(11) “Community water system” means a public water system which serves at least 15 service connections used by year round residents or regularly serves at least 25 year round residents.

(12) “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.

(13) “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.

(14) “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

(Rule 0400-45-01-.04, continued)

comprehensive performance evaluation must consist of at least the following components: assessment of plant performance; evaluation of major unit processes; identification and prioritization of performance limiting factors; assessment of the applicability of comprehensive technical assistance; and preparation of a CPE report.

(15) "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.

(16) "Connection" means the point at which there is a meter or service tap if no meter is present.

(17) "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.

(18) "Contaminant" means any physical, chemical, biological, or radiological substance or matter in water.

(19) "Conventional filtration treatment" means a series of processes including coagulation, flocculation, sedimentation, and filtration resulting in substantial particulate removal.

(20) "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.

(21) "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). "CT99.9" is the CT value required for 99.9 percent (3 log) inactivation of Giardia lamblia cysts. CT99.9 for a variety of disinfectants and conditions appear in Tables 1.1 through 1.6, 2.1, and 3.1 of part (5)(b)3. of Rule 0400-45-01-.31.

$$\frac{CTcalc}{CT_{99.9}}$$

is the inactivation ratio. The sum of the inactivation ratios, or total inactivation ratio shown as

$$\Sigma \frac{(CTcalc)}{(CT_{99.9})}$$

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.

(22) "Department" when used in these rules means the Division of Water Resources, Tennessee Department of Environment and Conservation, or one of the Division's field offices.

(23) "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 0400-45-01-.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.

(24) “Direct filtration” means a series of processes including coagulation and filtration but excluding sedimentation resulting in substantial particulate removal.

(25) “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.

(26) “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.

(27) “Disinfection” means a process which inactivates pathogenic organisms in water by chemical oxidants or equivalent agents.

(28) “Disinfection profile” is a summary of daily Giardia lamblia inactivation through the treatment plant. The procedure for developing a disinfection profile is contained in 40 CFR 141.172.

(29) “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.

(30) “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.

(31) “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).

(32) “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 Rule 0400-45-01-.37 and determining compliance with the TTHM and HAA5 MCLs under the provisions of Rule 0400-45-01-.38.

(33) “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.

(34) “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 0400-45-01-.04, continued)

(35) "Enhanced coagulation" means the addition of sufficient coagulant for improved removal of disinfection byproduct precursors by conventional filtration treatment.

(36) "Enhanced softening" means the improved removal of disinfection byproduct precursors by precipitative softening.

(37) "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.

(38) "Filtration" means a process for removing particulate matter from water by passage through porous media.

(39) "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).

(40) "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.

(41) "Flooculation" 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.

(42) "Flowing stream" is a course of running water flowing in a definite channel.

(43) "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.

(44) "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.

(45) "Gross Alpha Particle Activity" means the total radioactivity due to alpha particle emission as inferred from measurements on a dry sample.

(46) "Gross Beta Particle Activity" means the total radioactivity due to beta particle emission as inferred from measurements on a dry sample.

(47) "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 Department. The Department 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.

(48) "Haloacetic acids (five) (HAA5)" mean the sum of the concentrations in milligrams per liter of the haloacetic acid compounds (monochloroacetic acid, dichloroacetic acid, trichloroacetic

(Rule 0400-45-01-.04, continued)

acid, monobromoacetic acid, and dibromoacetic acid), rounded to two significant figures after addition.

(49) "Halogen" means one of the chemical elements chlorine, bromine or iodine.

(50) "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.

(51) "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
(b) Beryllium
(c) Cyanide
(d) Nickel
(e) Thallium
(f) dichloromethane
(g) 1,2,4-trichlorobenzene
(h) 1,1,2-trichloroethane
(i) dalapon
(j) dinoseb
(k) diquat
(l) endothall
(m) endrin
(n) glyphosate
(o) oxamyl
(p) picloram
(q) simazine
(r) benzo(a)pyrene
(s) di(2ethylhexyl)adipate
(t) di(2ethylhexyl)phthalate
(u) hexachlorobenzene
(v) hexachlorocyclopentadiene
(w) 2,3,7,8 TCDD

(52) "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.

(53) "Large water system" for the purpose of lead and copper rule, means a water system that serves more than 50,000 persons.

(54) "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.

(55) "Legionella" means a genus of bacteria, some species of which have caused a type of pneumonia called Legionnaires Disease.

(56) "Level 1 assessment" is an evaluation to identify the possible presence of sanitary defects, defects in distribution system coliform monitoring practices, and (when possible) the likely reason that the system triggered the assessment. It is conducted by the system operator or owner. Minimum elements include review and identification of atypical events that could affect distributed water quality or indicate that distributed water quality was impaired; changes in distribution system maintenance and operation that could affect distributed water quality (including water storage); source and treatment considerations that bear on distributed water quality, where appropriate (e.g., whether a ground water system is disinfected); existing water quality monitoring data; and inadequacies in sample sites, sampling protocol, and sample processing. The system must conduct the assessment consistent with any Department directives that tailor specific assessment elements with respect to the size and type of the system and the size, type, and characteristics of the distribution system.

(57) "Level 2 assessment" is an evaluation to identify the possible presence of sanitary defects, defects in distribution system coliform monitoring practices, and (when possible) the likely

(Rule 0400-45-01-.04, continued)

reason that the system triggered the assessment. A Level 2 assessment provides a more detailed examination of the system (including the system's monitoring and operational practices) than does a Level 1 assessment through the use of more comprehensive investigation and review of available information, additional internal and external resources, and other relevant practices. It is conducted by an individual approved by the Department, which may include the system operator. Minimum elements include review and identification of atypical events that could affect distributed water quality or indicate that distributed water quality was impaired; changes in distribution system maintenance and operation that could affect distributed water quality (including water storage); source and treatment considerations that bear on distributed water quality, where appropriate (e.g., whether a ground water system is disinfected); existing water quality monitoring data; and inadequacies in sample sites, sampling protocol, and sample processing. The system must conduct the assessment consistent with any Department directives that tailor specific assessment elements with respect to the size and type of the system and the size, type, and characteristics of the distribution system. The system must comply with any expedited actions or additional actions required by the Department in the case of an E. coli MCL violation.

(58) "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.

(59) "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.

(60) "Maximum contaminant level" or "MCL" 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 circumstances controlled by the user, except those resulting from corrosion of piping and plumbing caused by water quality, are excluded from this definition.

(61) "Maximum contaminant level goal" or "MCLG" means that the maximum level of the contaminant in drinking water at which no known or anticipated adverse effect on the health of persons would occur, and which allows an adequate margin of safety. Maximum contaminant level goals are non-enforceable health goals.

(62) "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.

(63) "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.

(Rule 0400-45-01-.04, continued)

(64) “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.

(65) “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.

(66) “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.

(67) “Non-community water system” means a public water system that is not a community water system. A non-community water system is either a “transient non-community water system” (TNCWS) or a “non-transient non-community water system” (NTNCWS).

(68) “Non-transient non-community water system” or “NTNCWS” means a non-community water system that regularly serves at least 25 of the same persons over six months per year.

(69) “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.

(70) “Person” means any individual, corporation, company, association, partnership, State, municipality, utility district, water cooperative, or Federal agency.

(71) “Picocurie” (pCi) means that quantity of radioactive material producing 2.22 nuclear transformations per minute.

(72) “Plan documents” means 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.

(73) “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.

(74) “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.

(75) “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.

(76) “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.

(77) “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.

(78) “Primary drinking water regulation” means a rule promulgated by the Board which:

(Rule 0400-45-01-.04, continued)

(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) Specifies for each such contaminant either:

1. A maximum contaminant level, 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 treatment technique known to the Department which leads to a reduction in the level of such contaminant sufficient to satisfy the requirements of Rule 0400-45-01-.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 regarding (i) the minimum quality of water which may be taken into the system and (ii) siting for new facilities for public water systems.

(79) “Public water system” means a system for the provision of piped water for human consumption if the system 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

(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.

(80) “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.

(81) “Repeat compliance period” means any subsequent compliance period after the initial compliance period.

(82) “Residual disinfectant concentration” (“C” in CT calculations) means the concentration of disinfectant measured in mg/l in a representative sample of water.

(83) “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.

(84) “Sanitary defect” is a defect that could provide a pathway of entry for microbial contamination into the distribution system or that is indicative of a failure or imminent failure in a barrier that is already in place.

(Rule 0400-45-01-.04, continued)

(85) "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.

(86) "Seasonal system" is a non-community water system that is not operated as a public water system on a year-round basis and starts up and shuts down at the beginning and end of each operating season.

(87) "Secondary drinking water regulation" means a rule promulgated by the Board which applies to public water systems and which specifies the maximum contaminant levels which, in the judgment of the Board, are requisite to protect the public welfare. Such rules may vary according to geographic and other circumstances, and may apply to any contaminant in drinking water which may:

(a) 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) Otherwise adversely affect the public welfare.

(88) "Sedimentation" means a process for removal of solids before filtration by gravity or separation.

(89) "Service line sample" means a one liter sample of water collected in accordance with part (7)(b)3. of Rule 0400-45-01-.33, that has been standing for at least 6 hours in a service line.

(90) "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.

(91) "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.

(92) "Small water system" for the purpose of the lead and copper rules only, means a water system that serves 3,300 or fewer persons.

(93) "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 of Rules 0400-45-01-.17, 0400-45-01-.31 and 0400-45-01-.39.

(94) "Supplier of water" means any person who owns or operates a public water system.

(95) "Surface water" means all water which is open to the atmosphere and subject to surface runoff.

(96) "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).

(97) "System with a single service connection" means a system which supplies drinking water to consumers via a single service line.

(Rule 0400-45-01-.04, continued)

(98) "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.

(99) "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.

(100) "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.

(101) "Transient non-community water system" or "TNCWS" means a non-community water system that regularly serves at least 25 individuals daily at least 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.

(102) "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.

(103) "Two-stage lime softening" is a process in which chemical addition and hardness precipitation occur in each of two distinct unit clarification processes.

(104) "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.

(105) "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 rules.

(106) "Virus" means a virus of fecal origin which is infectious to humans by waterborne transmission.

(107) "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.

(108) "Wholesale system" is a public water system that treats source water as necessary to produce finished water and then delivers some or all of that finished water to another public water system. Delivery may be through a direct connection or through the distribution system of one or more consecutive systems.

Authority: *T.C.A. §§ 4-5-201, et seq. and 68-221-701, et seq.* ***Administrative History:*** *Original rule filed August 1, 2012; effective October 30, 2012. Rule was previously numbered 1200-05-01. Amendments and new rules filed November 24, 2015; effective February 22, 2016. Amendments filed November 19, 2018; effective February 17, 2019.*

0400-45-01-.05 SUPERVISION OF DESIGN AND CONSTRUCTION.

(1) Engineering - Plan documents for public water systems shall be submitted to the Department at least thirty (30) days prior to the date on which action by the Department is desired.

(2) Expiration of Approval - Approval of engineering reports, proposals, preliminary plans, survey and basis of design data shall be null and void after a period of one year from the date

(Rule 0400-45-01-.05, continued)

(13) Delegation of Plans Review Authority - Under T.C.A § 68-221-706, any unit of local government may petition the Commissioner for certification to review and approve plans for water distribution facilities within its jurisdiction. The unit of local government must have adequate experience and expertise in water distribution and must adopt standards and impose requirements which are at least as stringent as the Department's. The request for certification must be in writing and contain at least the following:

(a) The names of the individual(s) responsible for the review and approval together with his/her experience and education. This person(s) must be employed by the unit of local government and be a registered professional engineer in Tennessee.

(b) A copy of the standards, requirements and design criteria legally adopted and enforceable by the unit of local government.

(c) The type of projects the unit of local government wishes to receive certification to review. This may include but is not limited to water lines, distribution pumping stations and distribution storage tanks.

(d) Procedures for maintaining records of all projects reviewed and approved by the unit of local government.

(e) The wording to be used on the approval stamp.

(f) Plans review authority fee.

The Division of Water Resources will be responsible for reviewing the application for certification and shall have up to 60 days from the receipt of the complete application to make a written response. Units of local government will not be certified to review projects involving state or federal funds, raw water pump stations, new water sources, treatment facilities, sludge handling facilities, or any project designed by the staff of the local government. Any unit of local government which receives certification for plans review shall submit one copy of any plan documents it has approved to the Division of Water Resources. 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 Resources 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. and 68-221-701, et seq.* ***Administrative History:*** *Original rule filed August 1, 2012; effective October 30, 2012. Rule was previously numbered 1200-05-01. Amendments filed November 19, 2018; effective February 17, 2019.*

0400-45-01-.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.

(b) The following are the maximum contaminant levels for inorganic chemicals:

CONTAMINANT	LEVEL, MILLIGRAMS PER LITER

(Rule 0400-45-01-.06, continued)

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 maximum contaminant levels for volatile organic chemicals are given in paragraph (2) of Rule 0400-45-01-.25.

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

(Rule 0400-45-01-.06, continued)

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 Rule 0400-45-01-.08.

(b) Two (2.0) turbidity units based on an average for two consecutive days pursuant to Rule 0400-45-01-.08.

To meet the maximum contaminant level for turbidity, a public water system must meet both subparagraphs (a) and (b) of this paragraph.

(4) Microbiological - The maximum contaminant levels for microbiologicals are applicable to both community water systems and non-community water systems.

(a) Until March 31, 2016, the total coliform maximum contaminant level (MCL) is based on the presence or absence of total coliforms in a sample, rather than coliform density. Beginning April 1, 2016, the MCL for total coliform shall no longer be in effect.

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 Department 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 Rule 0400-45-01-.19 using the language specified in Rule 0400-45-01-.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 Department within ten (10) days after the system discovers the violation and notify the public in accordance with Rule 0400-45-01-.19.

(b) Until March 31, 2016, 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 Rule 0400-45-01-.19, this is a 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 Department 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 Department before the end of the next business day.

(Rule 0400-45-01-.06, continued)

not under the direct influence of surface water must comply with this this part beginning January 1, 2004. All systems must comply with these MCLs until the date specified for Locational Running Annual Average (Stage 2 Disinfection Byproducts Requirements (LRAA)) compliance in Rule 0400-45-01-.38.

Disinfection by-product	MCL (mg/L)
Total trihalomethanes (TTHM)	0.080
Haloacetic acids (five) (HAA5)	0.060

(ii) The Administrator, pursuant to section 1412 of the Federal Safe Drinking Water Act, hereby identifies the following as the best technology, treatment techniques, or other means available for achieving compliance with the maximum contaminant levels for TTHM and HAA5 identified in this part.

Disinfection by-product	Best available technology
Total trihalomethanes (TTHM) and Haloacetic acids (five) (HAA5)	Enhanced coagulation or enhanced softening or GAC10, with chlorine as the primary and residual disinfectant

2. LRAA compliance (Rule 0400-45-01-.38)

(i) Compliance dates. The Stage 2 Disinfection Byproducts Requirements (LRAA) MCLs for TTHM and HAA5 must be complied with as a locational running annual average (LRAA) at each monitoring location beginning the date specified for Stage 2 Disinfection Byproducts Requirements (LRAA) compliance in subparagraph (1)(c) of Rule 0400-45-01-.38.

Disinfection by-product	MCL (mg/L)
Total trihalomethanes (TTHM)	0.080
Haloacetic acids (five) (HAA5)	0.060

(ii) The Administrator, pursuant to section 1412 of the Federal Safe Drinking Water Act, hereby identifies the following as the best technology, treatment techniques, or other means available for achieving compliance with the maximum contaminant levels for TTHM and HAA5 identified in this part for all systems that disinfect their source water:

Disinfection by-product	Best available technology
Total trihalomethanes (TTHM) and Haloacetic acids (five) (HAA5)	Enhanced coagulation or enhanced softening or GAC10; nanofiltration and with a molecular weight cutoff of equal to or less than 1000 Daltons; or GAC20

(iii) The Administrator, pursuant to section 1412 of the Federal Safe Drinking Water Act, hereby identifies the following as the best technology, treatment techniques, or other means available for achieving compliance with the maximum contaminant levels for TTHM and HAA5 identified in this part for consecutive systems and applies only to the disinfected water that consecutive systems buy or otherwise receive:

Disinfection by-product	Best available technology
Total trihalomethanes (TTHM) and	Systems serving 10,000 or more:

(Rule 0400-45-01-.06, continued)

Haloacetic acids (five) - (HAA5).	Improved distribution system and storage tank management to reduce residence time, plus the use of chloramines for disinfectant residual maintenance. Systems serving <10,000: Improved distribution system and storage tank management to reduce residence time.

(c) Maximum residual disinfectant levels.

1. Maximum residual disinfectant levels (MRDLs) are as follows:

Disinfectant residual	MRDL (mg/L)
Chlorine.....................................	4.0 (as Cl_2).
Chloramines.....................................	4.0 (as Cl_2).
Chlorine dioxide..............................	0.8 (as ClO_2).

(d) Compliance dates.

1. CWSs and NTNCWSs. Subpart H systems serving 10,000 or more persons must comply with MRDLs beginning January 1, 2002. Subpart H systems serving fewer than 10,000 persons and systems using only ground water not under the direct influence of surface water must comply with MRDLs beginning January 1, 2004.

2. Transient NCWSs. Subpart H systems serving 10,000 or more persons and using chlorine dioxide as a disinfectant or oxidant must comply with the chlorine dioxide MRDL beginning January 1, 2002. Subpart H systems serving fewer than 10,000 persons and using chlorine dioxide as a disinfectant or oxidant and systems using only ground water not under the direct influence of surface water and using chlorine dioxide as a disinfectant or oxidant must comply with the chlorine dioxide MRDL beginning January 1, 2004.

(e) Best Available Control Technology

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. §§ 4-5-201, et seq. and 68-221-701, et seq.* ***Administrative History:*** *Original rule filed August 1, 2012; effective October 30, 2012. Rule was previously numbered 1200-05-01. Amendments and new rules filed November 24, 2015; effective February 22, 2016. Amendments filed March 7, 2016; effective June 5, 2016.*

0400-45-01-.07 MONITORING AND ANALYTICAL REQUIREMENTS.

(1) Microbiological Contaminant Sampling

(a) Effective April 1, 2016, violations for total coliform and fecal coliform shall no longer be considered MCL violations and violations regarding total coliform shall be treatment

(Rule 0400-45-01-.07, continued)

technique triggers as described in Rule 0400-45-01-.41. Paragraph (5) of this rule further delineates the transition to Rule 0400-45-01-.41.

(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
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

of the first exceedance, unless the Department determines that the system, for reasons outside the system's control cannot have the sample analyzed within 30 hours of collection. Sample results from this coliform monitoring must be included in determining compliance with the MCL for total coliforms in paragraph (4) of Rule 0400-45-01-.06.

(g) Special purpose samples, such as those taken to determine whether disinfection practices are sufficient following pipe placement, replacement, or repair, shall not be used to determine whether the coliform treatment technique trigger has been exceeded compliance with the MCL for total coliforms in paragraph (4) of Rule 0400-45-01-.06 provided the water is not served to customers before negative analytical results are obtained. Samples representing water served to customers prior to obtaining analytical results shall not be special purpose samples and shall not count toward compliance with the MCL for total coliforms in paragraph (4) of Rule 0400-45-01-.06 with the MCL for total coliforms in paragraph (4) of Rule 0400-45-01-.06. After March 31, 2016, this subparagraph is no longer applicable.

(2) Repeat Monitoring

(a) If a routine sample is total coliform-positive, the public water system must collect a set of repeat samples within 24 hours of being notified of the positive result. A system which collects more than one routine sample per month must collect no fewer than three repeat samples for each total coliform-positive sample found. A system which collects one routine sample per month or fewer must collect no fewer than four repeat samples for each total coliform-positive sample found. The Department may extend the 24-hour limit on a case-by-case basis if the system has a problem in collecting the repeat samples within 24 hours that is beyond its control. In the case of an extension, the Department must specify how much time the system has to collect the repeat samples.

(b) The system must collect at least one repeat sample from the sampling tap where the original total coliform-positive sample was taken, and at least one repeat sample at a tap within five service connections upstream and at least one repeat sample at a tap within five service connections downstream of the original sampling site. If a total coliform-positive sample is at the end of the distribution system, or one away from the end of the distribution system, the Department may waive the requirement to collect at least one repeat sample upstream or downstream of the original sampling site.

(c) The system must collect all repeat samples on the same day and within 24 hours of being notified of a positive result, except that the Department may allow a system with a single service connection to collect the required set of repeat samples over a four consecutive day period or to collect a larger volume repeat sample(s) in one or more sample containers of any size, as long as the total volume collected is at least 400 ml (300 ml for systems which collect more than one routine sample per month.)

(d) If one or more repeat samples in the set is total coliform-positive, the public water system must collect an additional set of repeat samples in the manner specified in subparagraphs (a), (b), and (c) of this paragraph. The additional samples must be collected within 24 hours of being notified of the positive result, unless the Department extends the limit as provided in subparagraph (a) of this paragraph. The system must repeat this process until either total coliforms are not detected in one complete set of repeat samples or the system determines that the MCL for total coliforms in paragraph (4) of Rule 0400-45-01-.06 has been exceeded and notifies the Department.

(e) If a system normally collecting fewer than five routine samples per monitoring period has one or more total coliform-positive samples and the Department does not

(Rule 0400-45-01-.07, continued)

0400-45-01-.08 TURBIDITY SAMPLING AND ANALYTICAL REQUIREMENTS.

(1) Ground water sampling – Samples shall be taken by suppliers of water that serve more than 50 connections or that have been directed to conduct monitoring under paragraph (11) of Rule 0400-45-01-.05 for both community water systems and non–community water system at a representative entry point(s) to the water distribution system at least once per day for the purpose of making turbidity measurements to determine compliance with paragraph (3) of Rule 0400-45-01-.06. Public water systems using water from a source not under the direct influence of surface water are not required to monitor turbidity unless directed to do so under the provisions of paragraph (11) of Rule 0400-45-01-.05.

(2) Turbidity measurements of surface water and ground water under the direct influence that employs filtration - The minimum sampling requirements for systems using filtration treatment shall be as follows:

(a) Turbidity measurements must be performed on representative samples of the system's filtered water every four hours, (or more frequently, as authorized by the rules) that the system serves water to the public. A public water system may substitute continuous turbidity monitoring for grab samples if approved in writing by the Department. For systems serving 500 or fewer persons per day, the Department may allow the sampling frequency to be reduced to once per day if it determines that less frequent monitoring is sufficient to indicate effective filtration performance. Systems filtering surface water and ground water under the direct influence of surface water shall comply with the treatment technique standards found in paragraph (4) of Rule 0400-45-01-.31.

(3) Ground water systems under the direct influence of surface water and do not filter and have qualified to avoid filtration - The minimum sampling requirements for ground water systems under the direct influence of surface water and not employing filtration shall be as follows:

(a) Turbidity measurements must be performed on representative grab samples of source water immediately prior to the first or only point of disinfectant application every four hours (or more frequently, as authorized by the rules) that the system serves water to the public. A public water system may substitute continuous turbidity monitoring for grab sample monitoring if it validates the continuous measurement for accuracy on a regular basis using a protocol approved by the Department. Turbidity must comply with the limits specified in part (2)(a)2. of Rule 0400-45-01-.31.

(4) Reporting

(a) Ground water systems - All community water systems using a ground water source with turbidity removal facilities and not designated as ground water under the direct influence of surface water shall be required, if the results of a turbidity analysis indicate that the maximum allowable limit has been exceeded, to confirm by resampling as soon as practicable and preferably within one (1) hour. If the repeat sample confirms that the maximum allowable limit has been exceeded, the supplier of water shall report to the Department within forty-eight (48) hours. The repeat sample shall be the sample used for the purpose of calculating the monthly average. If the monthly average of the daily samples exceeds the maximum allowable limit, or if the average of two samples taken on consecutive days exceeds two (2) NTU, the supplier of water shall report to the Department and notify the public as directed in Rules 0400-45-01-.18 and 0400-45-01-.19. All non-community water systems using ground water formations, other than approved sand and gravel formations, may be required to monitor turbidity if the Department finds a system cannot meet the microbiological standard, the turbidity limit is exceeded, or if other health related problems exist.

(Rule 0400-45-01-.08, continued)

(b) Surface water systems and ground water systems under the direct influence of surface water - Turbidity measurements must be reported within 10 days after the end of each month the system serves water to the public. Information that must be reported includes but is not limited to:

1. The total number of filtered water turbidity measurements taken during the month.

2. The number and percentage of filtered water turbidity measurements taken during the month which are less than or equal to the applicable limits specified in paragraph (4) of Rule 0400-45-01-.31.

3. The date and value of any turbidity measurements taken during the month which exceed 5 NTU.

(c) Ground water systems under the direct influence of surface water that have qualified to avoid filtration - Information that must be reported includes but is not limited to:

1. The maximum turbidity level measured during the month, the date(s) of occurrence for any measurement(s) which exceeded 5 NTU, and the date(s) the occurrence(s) was reported to the Department.

2. For the first 12 months of recordkeeping, the dates and cumulative number of events during which the turbidity exceeded 5 NTU, and after one year of recordkeeping for turbidity measurements, the dates and cumulative number of events during which the turbidity exceeded 5 NTU in the previous 12 months the system served water to the public.

3. For the first 120 months of recordkeeping, the dates and cumulative number of events during which the turbidity exceeded 5 NTU, and after 10 years of recordkeeping for turbidity measurements, the dates and cumulative number of events during which the turbidity exceeded 5 NTU in the previous 120 months the system served water to the public.

(d) Ground water systems under the direct influence of surface water that has been directed to install filtration but has not yet done so shall monitor as specified in subparagraph (a) of this paragraph.

Authority: *T.C.A. §§ 4-5-201, et seq. and 68-221-701, et seq.* ***Administrative History:*** *Original rule filed August 1, 2012; effective October 30, 2012. Rule was previously numbered 1200-05-01.*

0400-45-01-.09 INORGANIC CHEMICAL SAMPLING AND ANALYTICAL REQUIREMENTS.

(1) Monitoring and analysis for the purpose of determining compliance with the maximum contaminant level for antimony, arsenic, asbestos, barium, beryllium, cadmium, chromium, cyanide, fluoride, mercury, nickel, nitrate, nitrite, total nitrate and nitrite, thallium, and selenium shall be conducted as follows:

(a) Groundwater systems shall take a minimum of one sample at every entry point to the distribution system which is representative of each well after treatment (hereafter called a sampling point) beginning in the compliance period starting January 1, 1993. The system shall take such sample at the same sampling point unless conditions make another sampling point more representative of each source or treatment plant.

(Rule 0400-45-01-.09, continued)

(a) Groundwater systems shall take one sample at each sampling point during each three year compliance period starting January 1, 1993. Surface water systems and combined surface/ground systems shall take one sample annually at each sampling point beginning January 1, 1993.

(b) Systems which exceed the maximum contaminant levels shall monitor quarterly beginning in the next quarter after the violation occurred.

(c) The Department may decrease the quarterly monitoring requirement to the frequencies specified in subparagraph (a) of this paragraph provided a ground water system has collected two consecutive quarterly samples and a surface water system has a minimum of four consecutive quarterly samples below the MCL.

(d) The system may apply to the Department for a waiver from the monitoring frequencies specified in subparagraph (a) of this paragraph. The Department may grant a public water system a waiver for monitoring cyanide, provided that the Department determines that the system is not vulnerable due to the lack of any industrial source of cyanide.

(e) A condition of the waiver shall require that a system shall take a minimum of one sample while the waiver is effective. The term during which the waiver is effective shall not exceed one compliance cycle (i.e., nine years).

(f) The Department may grant a waiver provided surface water systems have monitored annually for at least three years and groundwater systems have conducted a minimum of three rounds of monitoring. (At least one sample shall have been taken since January 1, 1990). Both surface and groundwater systems shall demonstrate that all previous analytical results were less than the maximum contaminant level. Systems that use a new water source are not eligible for a waiver until three rounds of monitoring from the new source have been completed.

(g) In determining the appropriate reduced monitoring frequency, the Department shall consider:

1. Reported concentrations from all previous monitoring;

2. The degree of variation in reported concentrations; and

3. Other factors which may affect contaminant concentrations such as changes in groundwater pumping rates, changes in the system's configuration, changes in the system's operating procedures, or changes in stream flows or characteristics.

(h) A decision by the Department to grant a waiver shall be made in writing and shall set forth the basis for the determination. The determination may be initiated by the Department or upon an application by the public water system. The public water system shall specify the basis for its request. The Department shall review and, where appropriate, revise its determination of the appropriate monitoring frequency when the system submits new monitoring data or when other data relevant to the system's appropriate monitoring frequency become available.

(5) All public water systems (community, non-transient non-community, and transient non-community systems) shall monitor to determine compliance with the maximum contaminant level for nitrate.

(a) Community and non-transient non-community water systems served by ground water system shall monitor annually beginning January 1, 1993. Community and non–

(Rule 0400-45-01-.09, continued)

transient systems served by surface water shall monitor quarterly beginning January 1, 1993.

(b) For community and non-transient non-community water systems, the repeat monitoring frequency for ground water systems shall be quarterly for at least one year following any one sample in which the concentration is greater than or equal to 50 percent of the MCL. The Department may allow a groundwater system to reduce the sampling frequency to annually after the results of four consecutive quarterly samples are below the MCL.

(c) For community and non-transient non-community water systems, the Department may allow a surface water system to reduce the sampling frequency to annually if all analytical results from four consecutive quarters are less than 50 percent of the MCL. A surface water system shall return to quarterly monitoring if any one sample is greater than or equal to 50 percent of the MCL.

(d) Each transient non-community water system shall monitor annually beginning January 1, 1993.

(e) After the initial round of quarterly sampling is completed, each community and non-transient non-community system which has been allowed to reduce its monitoring to annually shall take subsequent samples during the quarter(s) which previously resulted in the highest analytical result.

(6) All public water systems (community, non-transient non-community, and transient non-community systems) shall monitor to determine compliance with the maximum contaminant level for nitrite.

(a) All public water systems shall take one sample at each sampling point during the compliance period beginning January 1, 1993, and ending December 31, 1995.

(b) After the initial sample, systems where an analytical result for nitrite is less than 50 percent of the MCL shall monitor at the frequency determined by the Department in accordance with the criteria in subparagraph (4)(g) of this rule.

(c) For community, non-transient non-community, and transient non-community water systems, the repeat monitoring frequency for any water system shall be quarterly for at least one year following any one sample in which the concentration is greater than or equal to 50 percent of the MCL. The Department may allow a system to reduce the sampling frequency to annually after determining the system has four consecutive quarters of data less than the MCL.

(d) Systems which are monitoring annually shall take each subsequent sample during the quarter(s) which previously resulted in the highest analytical result.

(7) Confirmation samples:

(a) Where the results of sampling for asbestos, antimony, arsenic, barium, beryllium, cadmium, chromium, cyanide, fluoride mercury, nickel, selenium or thallium indicate an exceedance of the maximum contaminant level, the Department may require that one additional sample be collected as soon as possible after the initial sample was taken (but not to exceed two weeks after the date of the initial sample analysis) at the same sampling point.

(b) Where nitrate or nitrite sampling results indicate an exceedance of the maximum contaminant level, the system shall take a confirmation sample within 24 hours of the

(Rule 0400-45-01-.11, continued)

1. The Department may require more frequent monitoring than specified in subparagraphs (a) and (b) of this paragraph, or may require confirmation samples at its discretion. The results of the initial and confirmation samples will be averaged for use in compliance determinations.

2. Each public water systems shall monitor at the time designated by the Department during each compliance period.

3. Compliance: Compliance the radionuclide MCLs will be determined based on the analytical result(s) obtained at each sampling point. If one sampling point is in violation of an MCL, the system is in violation of the MCL.

   (i) For systems monitoring more than once per year, compliance with the MCL is determined by a running annual average at each sampling point. If the average of any sampling point is greater than the MCL, then the system is out of compliance with the MCL.

   (ii) For systems monitoring more than once per year, if any sample result will cause the running average to exceed the MCL at any sample point, the system is out of compliance with the MCL immediately.

   (iii) Systems must include all samples taken and analyzed under the provisions of this Rule in determining compliance, even if that number is greater than the minimum required.

   (iv) If a system does not collect all required samples when compliance is based on a running annual average of quarterly samples, compliance will be based on the running average of the samples collected.

   (v) If a sample result is less than the detection limit, zero will be used to calculate the annual average, unless a gross alpha particle activity is being used in lieu of radium-226 and/or uranium. If the gross alpha particle activity result is less than detection, 1/2 the detection limit will be used to calculate the annual average.

4. The Department has the discretion to delete results of obvious sampling or analytic errors.

5. If the MCL for radioactivity set forth in paragraph (5) of Rule 0400-45-01-.06 is exceeded, the operator of a community water system must give notice to the Department pursuant to Rule 0400-45-01-.20 and to the public as required by Rule 0400-45-01-.19.

Authority: *T.C.A. §§ 4-5-201, et seq. and 68-221-701, et seq.* ***Administrative History:*** *Original rule filed August 1, 2012; effective October 30, 2012. Rule was previously numbered 1200-05-01.*

0400-45-01-.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

(Rule 0400-45-01-.12, continued)

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
(m)	Aluminum	0.2
(n)	Silver	0.1

(2) The system may apply for monitoring waivers from the monitoring frequency specified in paragraph (1) of this rule. 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. and 68-221-701, et seq.* ***Administrative History:*** *Original rule filed August 1, 2012; effective October 30, 2012. Rule was previously numbered 1200-05-01.*

0400-45-01-.13 ALTERNATIVE ANALYTICAL TECHNIQUES.

If an alternative analytical technique is acceptable to the Administrator of the U.S. Environmental Protection Agency as being substantially equivalent to the prescribed test in both precision and accuracy as it relates to the determination of compliance with any maximum contaminant level, they shall become a part of these rules and regulations by inference.

Authority: *T.C.A. §§ 4-5-201, et seq. and 68-221-701, et seq.* ***Administrative History:*** *Original rule filed August 1, 2012; effective October 30, 2012. Rule was previously numbered 1200-05-01.*

(Rule 0400-45-01-.15, continued)

by the Environmental Protection Agency will have compliance with the MCL determined on the analytical results of its sampling.

(3) Those public water systems which purchase all their water and elect to use the analytical results of the system from which it purchases water shall be deemed to be in compliance with the monitoring and MCL requirements provided the seller of water is in compliance. Any violation of an MCL or monitoring requirement by the seller of water will constitute a violation for all systems which purchase water unless samples are taken as described in paragraph (2) of this rule.

(4) All public notification requirements as contained in Rule 0400-45-01-.19 are the responsibility of the individual public water system regardless of which public water system conducts the analysis.

(5) All public water systems must maintain records as required by Rule 0400-45-01-.20 of all analytical results which pertain to the system regardless of which system actually did the analysis.

Authority: *T.C.A. §§ 4-5-201, et seq. and 68-221-701, et seq.* ***Administrative History:*** *Original rule filed August 1, 2012; effective October 30, 2012. Rule was previously numbered 1200-05-01.*

0400-45-01-.16 SITING REQUIREMENTS.

(1) Before a person may enter into a financial commitment for or initiate construction of a new public water system or increase capacity of an existing public water system, he shall notify the Department and, to the extent practicable, avoid locating part or all of the new or expanded facility at a site which:

(a) Is subject to a significant risk from earthquakes, floods, fires, or other disasters which could cause a breakdown of the public water system or a portion thereof; or

(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 August 1, 2012; effective October 30, 2012. Rule was previously numbered 1200-05-01.*

0400-45-01-.17 OPERATION AND MAINTENANCE REQUIREMENTS.

(1) (a) All community water systems which are designated as a surface supply or groundwater under the direct influence of surface water 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 and groundwater under the direct influence of surface water filtration plants which have installed continuous monitoring equipment including equipment for turbidity and chlorine residual with alarms and/or shutdown ability may seek written 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 groundwater 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.

(Rule 0400-45-01-.17, continued)

(b) 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.

(c) Pursuant to T.C.A. § 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 the water supply system.

(d) 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 Chapter 0400-49-01. A violation of those rules is a violation of this rule as well.

(2) (a) 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 ten days 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.

(b) Water systems which desire to use their own forms to report the daily operating results to the Department must have prior written approval of the form from the Department.

(3) All water quality tests, other than those listed in Rule 0400-45-01-.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 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.

(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.

(Rule 0400-45-01-.17, continued)

(6) (a) Pursuant to T.C.A. § 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.

(b) 1. All community water systems must adopt an ordinance or policy outlining the prohibitions in subparagraph (a) of this paragraph and submit a copy of the executed ordinance or policy to the Department for written 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 hazards associated with cross-connections. The written plan must be approved by the Department.

2. After adoption and approval of the cross-connection ordinance or policy and plan, each community water system must establish an ongoing program to detect and eliminate or protect the system from hazards associated with cross-connections. Records of the cross-connection control program must be maintained by the supplier of water and shall include such items as date of inspection, person contacted, recommendations, follow-up, and testing results.

3. Cross-connection plans and policies shall present information in conformance with the “Cross-Connection Control Manual and Design Criteria for Cross-Connection Control Plans, Ordinances and Policies” as published by the Department.

4. Community water systems 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.

5. Non-community water systems shall ensure that unprotected cross-connections are not allowed to exist within the water system. The non-community water system shall conduct periodic inspections of the water system and maintain a statement of inspection completion to include acknowledgement of the hazards associated with cross-connections.

(7) All community water systems shall prepare and maintain an emergency operations plan in order to safeguard the water supply and to alert the 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 Department and shall be reviewed and approved in writing by the Department. Systems shall include a drought management plan as a part of the emergency operations plan. The emergency operations plan, including the drought management portion, shall be reviewed, updated, and submitted to the Department at least once every three years. The drought management plan portions of the emergency operations shall be submitted for approval as follows:

(a) Systems serving 3,000 or more connections including consecutive systems: June 30, 2016.

(b) Systems serving more than 1,000 connections and less than 3,000 connections including consecutive systems: June 30, 2017.

(Rule 0400-45-01-.17, continued)

(c) Systems serving 1,000 connections or less: June 30, 2018.

(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, water treatment facilities, and wells. Public water systems, construction contractors, and engineers shall follow the latest edition of the AWWA standards C-651, C-652, C-653, C-654, 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. In lieu of following AWWA standards or approved equivalent methods, public water systems, construction contractors, and engineers may write their own disinfection standard operating procedures. Disinfection standard operating procedures shall be approved in writing by the Department and be available during the inspection, construction, maintenance, or repair activity.

The documentation shall include disinfection procedures used, bacteriological sample results, construction logs, and repair logs and may include photographs where appropriate. All wells, 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 public water system for five years. 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, water treatment facilities, 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) Bacteriological Sampling 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 for finished water storage facilities, water treatment facilities, and wells shall be collected as specified by AWWA standards C-652, C-653, and C-654.

Adequacy of disinfection of new lines shall 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, the end point, and at the end of each branch line, unless written approval of alternate sampling frequency and distance between sampling points has been obtained from the Department. If the newly constructed facility yields positive bacterial samples,-the line shall be flushed, and re-sampled. If subsequent samples are positive, the line shall be re-disinfected, flushed and sampled again.

(c) Bacteriological Sampling of Existing Facilities

1. Finished water storage facilities, water treatment facilities, and wells that have been compromised and potential contamination is introduced during inspection or repair shall be disinfected, flushed, and sampled as specified by AWWA standards C-652, C-653, and C-654. Bacteriological samples shall be collected from a location representing the water contained in the compromised facility. The

repaired facility may be returned to service prior to obtaining bacteriological results.

2. Drinking water mains where positive pressure has not been maintained during inspection or repair shall be disinfected and flushed prior to being placed back in service. Disinfection and flushing shall be in accordance with AWWA standard C-651 or other method approved in writing by the Department. Bacteriological samples shall be collected immediately after the repair is completed and from a location representing the water contained in the repaired main. The repaired main may be returned to service prior to obtaining bacteriological results. If the repaired main has been placed back into service and yields positive bacteriological samples, the main shall be flushed and re-sampled. One sample is to be collected at the original positive site, one sample is to be collected upstream of the repair and one sample is to be collected in the downstream area of the repair. Sampling shall continue until the water is coliform free.

3. If one-half or more of the bacteriological samples collected from the repaired facility are total coliform positive, the system shall notify the Department 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.

4. 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 facility, the system shall notify the Department within 24 hours and issue a Tier 1 public notice using the language specified in Appendix B of Rule 0400-45-01-.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 and written approval from the Department 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 paragraph (4) of this rule 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

(Rule 0400-45-01-.17, continued)

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 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

(Rule 0400-45-01-.17, continued)

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.

(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

(Rule 0400-45-01-.17, continued)

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 Resources 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.

(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) Each public water system adjusting the fluoride content to the finished water must monitor for fluoride quarterly using a certified laboratory and the calculation of the fluoride level will be by running annual average. If the quarterly analysis of a water sample from a public water system by a certified laboratory confirms that the level of fluoride in the sample exceeds 1.5 mg/L, the public water system must provide notification to its customers of the exceedance in the same manner as prescribed in paragraph (8) of Rule 0400-45-01-.19. The water system must begin monthly fluoride monitoring using a certified laboratory for analysis. Once the monthly analyses confirm that the fluoride level is less than 1.5 mg/L for three (3) consecutive months, the public water system may resume quarterly monitoring for fluoride.

(Rule 0400-45-01-.17, continued)

The recommended level of fluoridation in the finished water is 0.7 mg/l. Any public water system which determines to initiate or permanently cease fluoridation treatment of its water supply shall notify its customers, the local environmental field office within the Department of Environment and Conversation, and the Commissioner of the Department of Health in the manner and within the timeframe as specified by T.C.A. § 68-221-708(c).

(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, pipe or plumbing fitting or fixture, solder, or flux which is used in the installation or repair of any public water system shall be lead free. The term “lead free” shall have the meaning given it in T.C.A. § 68-221-703.

(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.

(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

(Rule 0400-45-01-.17, continued)

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 0400-45-01-.17(30)1. and 0400-45-01-.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 0400-45-01-.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
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 0400-45-01-.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 Department 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.

(Rule 0400-45-01-.17, continued)

(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 and clearwells. Each community water system shall establish and maintain a maintenance file on each of its distribution storage tanks and clearwells. These maintenance files must be available for inspection by Department personnel. These files must include records of all routine water storage tank and clearwell inspections by system personnel, any reports of detailed professional inspections of the water storage facilities by contractor personnel, dates and details of routine tank cleanings and surface flushings, and dates and details of all tank and clearwell maintenance activities. The tank and clearwell inspection records shall include dates of the inspections; the sanitary, coating and structural conditions of the water storage facility; and all recommendations for needed maintenance activities. Community water systems shall have a professional inspection performed and a written report produced on each of their distribution storage tanks and clearwells at least once every five years. Non-community water systems shall have a professional inspection performed and written report produced on each of their atmospheric pressure and distribution storage tanks and clearwells 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 distribution system finished water storage tanks and clearwells shall comply with AWWA standard C-652-11 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.

(Rule 0400-45-01-.17, continued)

(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 Department’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 the Department. 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 and continuous turbidimeters are primary standards and materials suggested by the manufacturer such as sealed sample cells filled with metal oxide particles in a polymer gel and turbid glass tubes. All other reference materials for turbidimeter verifications must be approved in writing by the Department. 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 part (5)(c)1. of Rule 0400-45-01-.31 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 part (5)(c)4. of Rule 0400-45-01-.31 must be verified weekly.

Authority: *T.C.A. §§ 4-5-201, et seq. and 68-221-701, et seq.* ***Administrative History:*** *Original rule filed August 1, 2012; effective October 30, 2012. Rule was previously numbered 1200-05-01. Amendments*

(Rule 0400-45-01-.17, continued)
and new rules filed November 24, 2015; effective February 22, 2016. Amendments filed March 7, 2016; effective June 5, 2016. Amendments filed November 19, 2018; effective February 17, 2019.

0400-45-01-.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.

(2) All systems shall report to the Department within forty-eight (48) hours of the failure to comply with Departmental drinking water regulations or other requirements (including failure to comply with monitoring, maximum contaminant level or treatment technique requirements) set forth in these rules and regulations, and in case of any of the following events shall immediately notify the Department and responsible local officials:

(a) Any major breakdown or failure of equipment in water treatment process which affects the quality or quantity of the water leaving the treatment plant;

(b) Any serious loss of water service due to a failure of transmission or distribution facilities; or

(c) Any situation with the water system which presents or may present an imminent and substantial endangerment to health.

(3) Systems are not required to report analytical results to the Department in cases where a State laboratory performs the analysis and reports the results to the Department.

(4) The public water system, within 10 days of completing the public notification requirements under Rule 0400-45-01-.19 for the initial public notice and any repeat notices, must submit to the department a certification that it has fully complied with the public notification regulations. The public water system must include with this certification a representative copy of each type of notice distributed, published, posted and made available to the persons served by the system and to the media.

(5) The water supply system shall submit to the Department, within the time stated in the request, copies of any records required to be maintained under Rule 0400-45-01-.20 hereof or copies of any documents then in existence which the Department is entitled to inspect pursuant T.C.A. §§ 68-221-701 et seq.

(6) The owner or operator of a community water system or non-transient non-community water system who is required to monitor under unregulated contaminant monitoring and reporting as required by the Environmental Protection Agency shall send a copy of the results of such monitoring and any public notice issued under Rule 0400-45-01-.19 to the Department within 30 days of receipt of the results or issuance of the notice.

(7) The community water system or non-transient non-community water system shall furnish the following information on forms provided by the Department to the Department for each sample analyzed under unregulated contaminant monitoring and reporting as required by the Environmental Protection Agency:

(a) Results of all analytical methods, including negatives,

(b) Name and address of the system that supplied the sample,

(Rule 0400-45-01-.18, continued)

(c) Contaminant(s),

(d) Analytical method(s) used,

(e) Date of sample,

(f) Date of analysis.

(8) It shall be a violation of these regulations for any person, public water system, engineer, operator or certified laboratory to:

(a) Record data or information and/or report any inaccurate, misleading, false or information known or that should be known to be false; or

(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 Department.

(9) Electronic Reporting. A person is required to submit reports and certifications to the Department in order for a person to comply with this rule chapter (0400-45-01). The Commissioner may make forms available electronically or allow these reports to be submitted electronically and, if submitted electronically, then that electronic submission shall comply with the requirements of Chapter 0400-01-40.

Authority: *T.C.A. §§ 4-5-201, et seq. and 68-221-701, et seq.* ***Administrative History:*** *Original rule filed August 1, 2012; effective October 30, 2012. Rule was previously numbered 1200-05-01. Amendments filed November 19, 2018; effective February 17, 2019.*

0400-45-01-.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 0400-45-01-.19(1)(a). 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.

(Rule 0400-45-01-.19, continued)

6. Violation of the Surface Water Treatment Rule (SWTR) Rule 0400-45-01-.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 Rule 0400-45-01-.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 Department 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 paragraph (3) of Rule 0400-45-01-.40.

(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 Department 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 Department. 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 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.

(Rule 0400-45-01-.19, continued)

(a) Which violations or situations require a Tier 2 public notice? Table 0400-45-01-.19(3)(a) 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 0400-45-01-.19(3)(a)

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) of this rule 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 subparagraph (4)(a) of Rule 0400-45-01-.40.

(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 primacy agency 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 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. The Department will not allow through its rules or policies less frequent repeat notice for an MCL or treatment technique violation under Rule 0400-45-01-.07 (Monitoring) or Rule 0400-45-01-.41 (Revised Total Coliform Rule) or a treatment technique violation under Rule 0400-45-01-.31 (Filtration and Disinfection). Department 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 Department 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 subparagraph (2)(a) of this rule is required to protect public

(Rule 0400-45-01-.19, continued)

Appendix A to this rule identifies the tier assignment for each specific violation or situation.

Table 0400-45-01-.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 subparagraph (2)(a) of this rule 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 subparagraph (2)(a) of this rule 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 paragraph (7) of this rule;
5.	Exceedance of the fluoride secondary maximum contaminant level (SMCL), as required under paragraph (8) of this rule; and
6.	Reporting and Recordkeeping violations under Rule 0400-45-01-.41.

(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 part 1. of this subparagraph 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:

1. Unless directed otherwise by the Department in writing, community water systems must provide notice by:

(Rule 0400-45-01-.19, continued)

VOC	Volatile Organic Chemical

Authority: *T.C.A. §§ 4-5-201, et seq. and 68-221-701, et seq.* ***Administrative History:*** *Original rule filed August 1, 2012; effective October 30, 2012. Rule was previously numbered 1200-05-01. Amendments and new rules filed November 24, 2015; effective February 22, 2016. Amendments filed November 19, 2018; effective February 17, 2019.*

0400-45-01-.20 RECORDS MAINTENANCE.

(1) Any owner or operator of a public water system subject to the provisions of these rules shall retain on its premises or at a convenient location near its premises the following records:

(a) Records of bacteriological analysis made pursuant to these rules shall be kept for not less than five (5) years. Records of chemical analyses made pursuant to these rules shall be kept for not less than ten (10) years. Actual laboratory reports may be kept, or data may be transferred to tabular summaries, provided that the following information is included:

1. The date, place, and time of sampling, the name of the person who collected the sample;

2. Identification of the sample as to whether it was a routine distribution system sample, repeat sample, raw or process water sample or other special purpose sample;

3. Date of analysis;

4. Laboratory and person responsible for performing analysis;

5. The analytical technique/method used; and

6. The results of the analysis.

(b) Records of action taken by the system to correct violations of primary drinking water regulations shall be kept for a period not less than three (3) years after the last action taken with respect to the particular violation involved.

(c) Copies of any written reports, summaries or communications relating to sanitary surveys of the system conducted by the system itself, by a private consultant, or by any State or Federal agency, shall be kept for a period not less than ten (10) years after completion of the sanitary survey involved.

(d) Records concerning a variance or exemption granted to the system shall be kept for a period ending not less than five (5) years following the expiration of such variance or exemption.

(e) Any such reports required by the Department shall be available for inspection by the public at the appropriate public water system office during regular business hours.

(f) Records of turbidity analysis shall be maintained for not less than five years. These records shall include daily worksheets, calibration data and strip charts. The strip charts shall be labeled each day the system operates with the date, time, place of collection, operator's initials, and the operating scale of the instrument.

(Rule 0400-45-01-.20, continued)

(g) Daily worksheets, strip charts, and shift logs used in the production of monthly operation reports or operation control of the plant shall be maintained for a minimum of five years.

(h) Cross-connection plans and inspection records, complaint logs, facility maintenance records, and storage tank inspection records shall be kept for 5 years.

(i) Copies of the public notices issued and certifications made to the Department pursuant to Rule 0400-45-01-.19 must be kept for three years after issuance.

(j) Any system subject to the requirements of Rule 0400-45-01-.33 shall retain on its premises original records of all sampling data and analyses, reports, surveys, letters, evaluations, schedules, Department determinations, and any other information required by paragraphs (2) through (9) of Rule 0400-45-01-.33. Each water system shall retain the records required by this rule for no fewer than 12 years.

(k) Copies of monitoring plans developed pursuant to this Chapter shall be kept for the same period of time as the records of analyses taken under the plan are required to be kept under subparagraph (a) of this paragraph, except as specified elsewhere in this chapter.

Authority: *T.C.A. §§ 4-5-201, et seq. and 68-221-701, et seq.* ***Administrative History:*** *Original rule filed August 1, 2012; effective October 30, 2012. Rule was previously numbered 1200-05-01.*

0400-45-01-.21 MONITORING FOR CORROSIVITY CHARACTERISTICS.

(1) Community water supply systems shall identify whether the following construction materials are present in their distribution system and report to the Department.

(a) Piping, solder, caulking, interior lining of distribution mains, service lines, and home plumbing made of lead;

(b) Piping and alloys, service lines, and home plumbing made of copper;

(c) Galvanized piping, service lines, and home plumbing;

(d) Ferrous piping materials such as cast iron and steel;

(e) Asbestos cement pipe;

(f) Vinyl lined asbestos cement pipe;

(g) Coal tar lined pipes and tanks.

Authority: *T.C.A. §§ 4-5-201, et seq. and 68-221-701, et seq.* ***Administrative History:*** *Original rule filed August 1, 2012; effective October 30, 2012. Rule was previously numbered 1200-05-01.*

0400-45-01-.22 RESERVED.

Authority: *T.C.A. §§ 4-5-201, et seq. and 68-221-701, et seq.* ***Administrative History:*** *Original rule filed August 1, 2012; effective October 30, 2012. Rule was previously numbered 1200-05-01.*

0400-45-01-.23 RESERVED.

Authority: *T.C.A. §§ 4-5-201, et seq. and 68-221-701, et seq.* ***Administrative History:*** *Original rule filed August 1, 2012; effective October 30, 2012. Rule was previously numbered 1200-05-01.*

(Rule 0400-45-01-.31, continued)

a surface water source or a ground water source under the direct influence of surface water must provide treatment of that source water that complies with these treatment technique requirements. These regulations establish treatment technique requirements in lieu of maximum contaminant levels for Giardia lamblia, cryptosporidium, viruses, heterotrophic plate count bacteria, Legionella, and turbidity. The treatment technique requirements consist of installing and properly operating water treatment processes which reliably achieve removal of Giardia lamblia cysts, cryptosporidium and viruses as set forth herein.

(b) A public water system using a ground water source under the direct influence of surface water shall:

1. Meet the requirements for avoiding filtration in paragraph (2) of this rule and meet the disinfection requirements in subparagraph (3)(a) of this rule; or

2. Meet the filtration requirements in paragraph (4) of this rule and the disinfection requirements in paragraph (30) of Rule 0400-45-01-.17.

(c) A public water supply using surface water shall meet disinfection requirements in paragraph (30) of Rule 0400-45-01-.17 and filtration requirements in paragraph (4) of this rule to be in compliance with paragraph (a) of this paragraph.

(d) Each public water system using a surface water source or a ground water source under the direct influence of surface water must be operated by certified personnel who meet the requirements of the Tennessee Water Environmental Health Act T.C.A. §§ 68-221-901 et seq. and Certification Board Regulations contained in Chapter 0400-49-01.

(e) Beginning December 31, 2001, subpart H systems serving 10,000 or more persons shall install treatment which achieve at least 99 percent (2-log) removal of cryptosporidium 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 filtered systems, and ground water systems under the direct influence of surface water and serving 10,000 or more persons must have a watershed control plan which controls cryptosporidium. Subpart H systems shall conduct filter and disinfection profiling and benchmarking as required by this rule. Subpart H systems serving 10,000 or more persons shall also comply with the turbidity criteria in subparagraph (4)(c) of this rule.

(f) Subpart H systems that did not conduct optional monitoring under paragraph (8) of this rule [Profiling and Benchmarking] because they served fewer than 10,000 persons in 2002, but serve more than 10,000 persons prior to January 14, 2005, must comply with the filtration, disinfection, and treatment technique requirements of this rule, or meet the criteria to avoid filtration. They shall also comply with the individual filter effluent turbidity monitoring, and other monitoring and reporting requirements of this rule. These systems must also consult with the Department to establish a disinfection benchmark. A system that decides to make a significant change to its disinfection practice as described in subparagraph (8)(e) of this rule must obtain approval from the department prior to making such change.

(2) Criteria for Avoiding Filtration for Ground Water Systems Impacted by Surface Water.

A public water system that uses a ground water source under the direct influence of surface water must meet all of the conditions of subparagraphs (a) and (b) of this paragraph and is subject to subparagraph (c) of this paragraph, beginning 18 months after the Department determines that it is under the direct influence of surface waters or December 30, 1991, whichever is later, unless the Department has determined, in writing, that filtration is required.

(Rule 0400-45-01-.31, continued)

(c) By December 31, 2001, subpart H systems that use conventional or direct filtration and serve 10,000 or more persons and by January 14, 2005, subpart H systems serving fewer than 10,000 persons shall employ filtration treatment that:

1. For systems using conventional filtration or direct filtration, the turbidity level of representative samples of a system's filtered water must be less than or equal to 0.3 NTU in at least 95 percent of the measurements taken each month, measured as specified in subparagraphs (5)(a) and (c) of this rule.

2. The turbidity level of representative samples of a system's filtered water must at no time exceed 1 NTU, measured as specified in subparagraphs (5)(a) and (c) of this rule.

3. A system that uses lime softening may acidify representative samples prior to analysis using a protocol approved by the Department.

(d) A public water system may use a filtration technology not listed in subparagraph (c) of this paragraph or in subparagraph (b) of this paragraph if it demonstrates to the Department, using pilot plant studies or other means, that the alternative filtration technology, in combination with disinfection treatment that meets the requirements of paragraph (30) of Rule 0400-45-01-.17, consistently achieves 99.9 percent removal and/or inactivation of Giardia lamblia cysts and 99.99 percent removal and/or inactivation of viruses, and 99 percent removal of Cryptosporidium oocysts, and the Department approves the use of the filtration technology. For each approval, the Department will set turbidity performance requirements that the system must meet at least 95 percent of the time and that the system may not exceed at any time at a level that consistently achieves 99.9 percent removal and/or inactivation of Giardia lamblia cysts, 99.99 percent removal and/or inactivation of viruses, and 99 percent removal of Cryptosporidium oocysts. The maximum allowable turbidity limits for subpart H systems serving fewer than 10,000 persons using an alternative filtration technology excluding slow sand and diatomaceous earth cannot exceed 1 NTU in 95 percent of the samples taken each month or 5 NTU on any single sample.

(5) Monitoring Requirements

(a) Reserved

(b) A public water system that uses a groundwater source under the direct influence of surface water and does not provide filtration treatment must comply with the maximum contaminant level (MCL) for total coliforms in paragraph (4) of Rule 0400-45-01-.06 and the MCL for E. coli in subparagraph (4)(g) of Rule 0400-45-01-.06. The system must achieve the standard at a frequency of at least 11 months of the 12 previous months that the system served water to the public, on an ongoing basis, unless the Department determines that failure to meet this requirement was not caused by a deficiency in treatment of the source water.

1. Fecal coliform or total coliform density measurements as required by part (2)(a)1 of this rule must be performed on representative source water samples immediately prior to the first or only point of disinfectant application. The system must sample for fecal or total coliforms at the following minimum frequency each week the system serves water to the public. Fecal coliform or total coliform densities must meet the limits specified in part (2)(a)1 of this rule.

System size (persons served)	Samples/week[1]
≤500	1

exceedance is known, in accordance with the requirements of Rule 0400-45-01-.19.

(iii) If at any time the disinfectant residual falls below 0.2 mg/l in the water entering the distribution system, the system must notify the Department as soon as possible, but no later than by the end of the next business day. The system also must notify the Department by the end of the next business day whether or not the residual was restored to at least 0.2 mg/l within 4 hours.

(b) A public water system that uses a surface water source or a ground water source under the direct influence of surface water and provides filtration treatment must report monthly to the Department the information specified in this subparagraph beginning June 29, 1993, or when filtration is installed, whichever is later.

1. Turbidity measurements as required by part (5)(c)1. of this rule must be reported within 10 days after the end of each month the system serves water to the public. Information that must be reported includes but is not limited to:

(i) The total number of filtered water turbidity measurements taken during the month.

(ii) The number and percentage of filtered water turbidity measurements taken during the month which are less than or equal to the applicable limits specified in paragraph (4) of this rule.

(iii) The date and value of any turbidity measurements taken during the month which exceed 5 NTU.

2. Disinfection information specified in subparagraph (5)(c) of this rule must be reported to the Department within 10 days after the end of each month the system serves water to the public. Information that must be reported includes:

(i) For each day, the lowest measurement of residual disinfectant concentration in mg/l in water entering the distribution system.

(ii) The date and duration of each period when the residual disinfectant concentration in water entering the distribution system fell below 0.2 mg/l and when the Department was notified of the occurrence.

(iii) The following information on the samples taken in the distribution system in conjunction with total monitoring pursuant to 0400-45-01-.07;

(I) Number of instances where the free residual disinfectant concentration is measured.

(II) The number of instances where the free residual is below 0.2 mg/l.

3. (i) Each system, upon discovering that a waterborne disease outbreak potentially attributable to that water system has occurred, must report that occurrence to the Department as soon as possible, but no later than by the close of the following business day.

(ii) If at any time the turbidity exceeds 1 NTU in representative samples of filtered water in a system using conventional filtration treatment or direct filtration, the system must consult with the department as soon as practical, but no later than 24 hours after the exceedance is known, in accordance with the requirements of Rule 0400-45-01-.19. If at any time the turbidity in representative samples of filtered water exceed the maximum level set by the department for filtration technologies other than conventional and direct filtration treatment, the system must consult with the department as soon as practical, but not later than 24 hours after the exceedance is known, in accordance with Rule 0400-45-01-.19.

(iii) If at any time the disinfectant residual falls below 0.2 mg/l in the water entering the distribution system, the system must notify the Department as soon as possible, but no later than by the end of the next business day. The system also must notify the Department by the end of the next business day whether or not the residual was restored to at least 0.2 mg/l within 4 hours.

4. In addition to the reporting and recordkeeping requirements in parts 1., 2., and 3. of this subparagraph, water systems serving 10,000 or more persons that provides conventional filtration treatment or direct filtration must report monthly to the Department the information specified in this part beginning January 1, 2002. In addition to the reporting and recordkeeping requirements in parts 1., 2., and 3. of this rule, a public water system serving fewer than 10,000 persons that provides conventional filtration treatment or direct filtration must report monthly to the Department the information specified in this part beginning January 14, 2005. In addition to the reporting and recordkeeping requirements in this paragraph, a public water system serving 10,000 or more persons that provides filtration approved under subparagraph (4)(d) of this rule must report monthly to the Department the information specified in subpart (i) of this part beginning January 1, 2002. In addition to the reporting and recordkeeping requirements in this paragraph, a public water system serving fewer than 10,000 persons that provides filtration approved under subparagraph (4)(d) of this rule must report monthly to the Department the information specified in subpart (i) of this part beginning January 14, 2005. The reporting in subpart (i) of this part is in lieu of the reporting specified in part 1. of this subparagraph.

(i) Turbidity measurements as required by this rule must be reported within 10 days after the end of each month the system serves water to the public. Information that must be reported includes:

(I) The total number of filtered water turbidity measurements taken during the month.

(II) The number and percentage of filtered water turbidity measurements taken during the month which are less than or equal to the turbidity limits specified in subparagraph (4)(c) or (d) of this rule.

(III) The date and value of any turbidity measurements taken during the month which exceed 1 NTU for systems using conventional filtration treatment or direct filtration, or which exceed the maximum level set by the Department under subparagraph (4)(d) of this rule.

(ii) Systems must maintain the results of individual filter monitoring taken for at least five years.

(I) For any individual filter that has a measured turbidity level of greater than 1.0 NTU in two consecutive measurements taken 15 minutes apart, the system must report the filter number, the turbidity measurement, and the date(s) on which the exceedance occurred. In addition, the system must either produce a filter profile for the filter within 7 days of the exceedance (if the system is not able to identify an obvious reason for the abnormal filter performance) and report that the profile has been produced or report the obvious reason for the exceedance.

(II) For any individual filter that has a measured turbidity level of greater than 0.5 NTU in two consecutive measurements taken 15 minutes apart at the end of the first four hours of continuous filter operation after the filter has been backwashed or otherwise taken offline, the system must report the filter number, the turbidity, and the date(s) on which the exceedance occurred. In addition, the system must either produce a filter profile for the filter within 7 days of the exceedance (if the system is not able to identify an obvious reason for the abnormal filter performance) and report that the profile has been produced or report the obvious reason for the exceedance.

(III) For any individual filter that has a measured turbidity level of greater than 1.0 NTU in two consecutive measurements taken 15 minutes apart at any time in each of three consecutive months, the system must report the filter number, the turbidity measurement, and the date(s) on which the exceedance occurred. In addition, the system must conduct a self-assessment of the filter within 14 days of the exceedance and report that the self-assessment was conducted. The self assessment must consist of at least the following components: assessment of filter performance; development of a filter profile; identification and prioritization of factors limiting filter performance; assessment of the applicability of corrections; and preparation of a filter self-assessment report.

(IV) For any individual filter that has a measured turbidity level of greater than 2.0 NTU in two consecutive measurements taken 15 minutes apart at any time in each of two consecutive months, the system must report the filter number, the turbidity measurement, and the date(s) on which the exceedance occurred. In addition, the system must arrange for the conduct of a comprehensive performance evaluation by the Department or a third party approved by the Department no later than 30 days following the exceedance and have the evaluation completed and submitted to the Department no later than 90 days following the exceedance.

(7) Variances and Exemptions from the Requirements of Filtration and Disinfection

(a) No variance from the requirements in this rule are permitted.

(b) No exemptions from the requirements in part (3)(a)3. of this rule and paragraph (30) of Rule 0400-45-01-.17 to provide disinfection are permitted.

(8) Disinfection Profiling and Benchmarking

(a) Subpart H public water systems serving 10,000 or more persons must conduct monitoring for haloacetic acids and trihalomethanes or conduct disinfection profiling. By January 14, 2005, subpart H public water systems must develop a disinfection profile unless the Department determines it is not necessary. Those systems that exceed 0.064 mg/L of total trihalomethanes or 0.048 mg/L of total haloacetic acids annual arithmetic average based on four quarters of data must calculate disinfection profiles. Subpart H systems that serve between 500 and 9,999 persons must begin to collect data needed to calculate disinfection profiles or demonstrate exemption from the profiling requirements no later than July 1, 2003. Subpart H systems serving fewer than 500 persons must begin to collect data for profiling or demonstrate exemption from the profiling requirements no later than July 1, 2004. Systems that must calculate profiles and that are planning changes in the disinfection process must also calculate disinfection benchmarks and submit the benchmark calculations with engineering plans for Departmental approval prior to making any process changes. Sampling analytical methods, frequency of sampling, and sample locations must be in accordance with procedures described in Rules 0400-45-01-.14 and 0400-45-01-.36. Disinfection profiles and benchmarks must be determined by calculating daily inactivation ratios in accordance with Departmental and EPA rules. Systems may elect to calculate profiles in lieu of conducting trihalomethanes and haloacetic acid monitoring for the purpose of complying with the disinfection and filtration rule.

(b) The department may approve the use of a more representative set of annual data for disinfection profiling. Systems that elect to conduct disinfection profiling rather than monitoring must notify the department. Systems may use existing data if approved by the department to comply with the disinfection byproduct monitoring or profiling required by this rule.

(c) A system that uses chloramines, chlorine dioxide, or ozone for a primary disinfectant must calculate the logs of inactivation for viruses using a method approved by the department.

(d) The system subject to the profiling requirements must retain disinfection profiles data in graphic form, such as a spreadsheet, or in some other format acceptable to the department for review during sanitary surveys.

(e) Any system that decides to change its disinfection practices must submit plans to the department for approval prior to making any changes. Changes to disinfection practices include but are not limited to:

1. Changes to the point of disinfection application;

2. Change in the disinfectant used;

3. Change in the disinfectant process, and

4. Any other modification identified by the department.

(f) Any system subject to the profiling requirements of this rule shall calculate its disinfection benchmark using methods approved by the department. A disinfection benchmark is the lowest monthly average value of the monthly logs of Garidia lamblia inactivation. A system using ozone or chloramines must also calculate the disinfection benchmark for viruses using methods approved by the department.

(9) Recycle Provisions

(a) Applicability. All subpart H systems that employ conventional filtration or direct filtration treatment and that recycle spent filter backwash water, thickener supernatant, or liquids from dewatering processes must meet the requirements in subparagraphs (b) through (d) of this paragraph.

(Rule 0400-45-01-.31, continued)

(b) Reporting. A system must notify the department in writing by December 8, 2003, if the system recycles spent filter backwash water, thickener supernatant, or liquids from dewatering processes. This notification must include, at a minimum, the information specified in parts 1. and 2. of this subparagraph.

1. A plant schematic showing the origin of all flows which are recycled (including, but not limited to, spent filter backwash water, thickener supernatant, and liquids from dewatering processes), the hydraulic conveyance used to transport them, and the location where they are re-introduced back into the treatment plant.

2. Typical recycle flow in gallons per minute (gpm), the highest observed plant flow experienced in the previous year (gpm), design flow for the treatment plant (gpm), and department-approved operating capacity for the plant where the department has made such determinations.

(c) Treatment technique requirement. Any system that recycles spent filter backwash water, thickener supernatant, or liquids from dewatering processes must return these flows through the processes of a system's existing conventional or direct filtration system as defined in Rule 0400-45-01-.04 or at an alternate location approved by the Department by June 8, 2004. If capital improvements are required to modify the recycle location to meet this requirement, all capital improvements must be completed no later than June 8, 2006.

(d) Recordkeeping. The system must collect and retain on file recycle flow information specified in parts 1. through 6. of this subparagraph for review and evaluation by the Department beginning June 8, 2004.

1. Copy of the recycle notification and information submitted to the Department under subparagraph (b) of this paragraph.

2. List of all recycle flows and the frequency with which they are returned.

3. Average and maximum backwash flow rate through the filters and the average and maximum duration of the filter backwash process in minutes.

4. Typical filter run length and a written summary of how filter run length is determined.

5. The type of treatment provided for the recycle flow.

6. Data on the physical dimensions of the equalization and/or treatment units, typical and maximum hydraulic loading rates, type of treatment chemicals used and average dose and frequency of use, and frequency at which solids are removed, if applicable.

Authority: *T.C.A. §§ 4-5-201, et seq. and 68-221-701, et seq.* ***Administrative History:*** *Original rule filed August 1, 2012; effective October 30, 2012. Rule was previously numbered 1200-05-01. Amendments and new rules filed November 24, 2015; effective February 22, 2016. Amendments filed November 19, 2018; effective February 17, 2019.*

0400-45-01-.32 FEES FOR PUBLIC WATER SYSTEMS.

(1) Annual facility maintenance fee - On the due date specified in the invoice from the Department, all public water systems shall pay the following fees to the Department:

(a) Community Water Systems

(Rule 0400-45-01-.32, continued)

(e) Community water systems with less than fifteen (15) service connections that are strictly wholesalers of water: $500

Authority: *T.C.A. §§ 4-5-201, et seq.; 68-203-101, et seq.; and 68-221-701, et seq.* ***Administrative History:*** *Original rule filed August 1, 2012; effective October 30, 2012. Rule was previously numbered 1200-05-01.*

0400-45-01-.33 CONTROL OF LEAD AND COPPER.

(1) General Requirements

(a) Applicability

1. The requirements of this rule constitute primary drinking water regulations for lead and copper. Unless otherwise indicated each of the provisions of this rule apply to community and non-transient, non-community water systems.

2. Reserved

(b) Scope. These regulations establish a treatment technique that includes requirements for corrosion control treatment, source water treatment, lead service line replacement, and public education. These actions are triggered, in some cases, by lead and copper action levels measured in samples collected at consumers' tap.

(c) Lead and Copper action levels.

1. The lead action level is exceeded if the concentration of lead in more than 10 percent of tap water samples collected during any monitoring period is greater than 0.015 mg/l (i.e., if the "90th percentile" lead level is greater than 0.015 mg/l).

2. The copper action level is exceeded if the concentration of copper in more than 10 percent of tap water samples collected during any monitoring period is greater than 1.3 mg/l (i.e., if the "90th percentile" copper level is greater than 1.3 mg/l).

3. The 90th percentile lead and copper levels shall be computed as follows:

(i) The results of all lead or copper samples taken during a monitoring period shall be placed in ascending order from the sample with the lowest concentration to the sample with the highest concentration. Each sampling result shall be assigned a number, ascending by single integers beginning with the number 1 for the sample with the lowest contaminant level. The number assigned to the sample with the highest contaminant level shall be equal to the total number of samples taken.

(ii) The number of samples taken during the monitoring period shall be multiplied by 0.9.

(iii) The contaminant concentration in the numbered sample yielded by the calculation in subpart (ii) of this part is the 90th percentile contaminant level.

(iv) For water systems serving fewer than 100 people that collect 5 samples per monitoring period, the 90th percentile is computed by taking the average of the highest and second highest concentrations.

(Rule 0400-45-01-.33, continued)

(v) For a public water system that has been allowed by the Department to collect fewer than five samples in accordance with subparagraph (7)(c) of this rule, the sample result with the highest concentration is considered the 90th percentile value.

(d) Corrosion control treatment requirements.

1. All water systems shall install and operate optimal corrosion control treatment as defined in Rule 0400-45-01-.04.

2. Any water system that complies with the applicable corrosion control treatment requirements set forth in paragraphs (2) and (3) of this rule shall be deemed in compliance with the treatment requirement contained in part 1. of this subparagraph.

(e) Source water treatment requirements. Any system exceeding the lead or copper action level shall implement all applicable source water treatment requirements set forth in paragraph (4) of this rule.

(f) Lead service line replacement. Any system exceeding the lead action level after implementation of applicable corrosion control and source water treatment requirements shall complete the lead service line replacement requirements set forth in paragraph (5) of this rule.

(g) Public education requirements. Pursuant to paragraph (6) of this rule, all water systems must provide a consumer notice of lead tap water monitoring results to persons served at the sites (taps) that are tested. Any system exceeding the lead action level shall implement the public education requirements set forth in paragraph (6) of this rule.

(h) Monitoring and analytical requirements. Tap water monitoring for lead and copper, monitoring for water quality parameters, source water monitoring for lead and copper, and analysis of the monitoring results shall be completed in compliance with paragraphs (7), (8), (9) and (10) of this rule.

(i) Reporting Requirements. Systems shall report to the Department any information required by the treatment provisions of this rule.

(j) Recordkeeping requirements. Systems shall maintain records in accordance with paragraph (12) of this rule.

(k) Violation of primary drinking water regulations. Failure to comply with the applicable requirements of this rule, including requirements established by the Department pursuant to these provisions, shall constitute a violation of the primary drinking water regulations for lead and/or copper.

(2) Applicability of corrosion control treatment steps to small, medium and large water systems.

(a) Systems shall complete the applicable corrosion control treatment requirements described in paragraph (3) of this rule by the deadlines established in this paragraph.

1. A large system (serving > 50,000 persons) shall complete the corrosion control treatment steps specified in subparagraph (d) of this paragraph, unless it is deemed to have optimized corrosion control under part (b)2. or 3. of this paragraph.

COMMUNITY

PUBLIC WATER SYSTEMS

DESIGN CRITERIA

Division of Water Resources

Tennessee Department of Environment and Conservation

2018

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Part 4 - TREATMENT

4.0 GENERAL - The design of treatment processes and devices depends on evaluation of the nature and quality of the particular water to be treated and the desired quality of the finished water. Surface water treatment plants must provide treatment for cryptosporidium, giardia, bacteria and viruses in accordance with the requirements of Division of Water Resources surface water treatment rules. Surface water treatment plants must provide for taste and odor control if there is any history or potential of taste and odor problems/complaints. Surface water treatment plants must be designed for control and reduction of disinfection by-products and their precursors.

4.1 CLARIFICATION - Plants designed for processing surface waters should:

a. provide duplicate units for flocculation and sedimentation,

b. be constructed to permit units to be taken out of service without disrupting operation.

4.1.1 Pre-sedimentation - Waters containing high turbidity or silica particles may require pretreatment, usually sedimentation either with or without the addition of coagulation chemicals.

a. Basin Design - Pre-sedimentation basins should be designed to hold maximum 3-day usage.

b. Inlet - Incoming water shall be dispersed across the full width of the line of travel as quickly as possible; short circuiting must be prevented.

c. Bypass - Provisions for bypassing pre-sedimentation basins shall be included.

4.1.2 Mixing (Flash or Quick):

a. Equipment - Basins should be equipped with mechanical mixing devices; other arrangements, such as baffling, and in-line mixers may be acceptable.

b. Mixing - The detention period shall not exceed 30 seconds. Concrete blocks may be placed in the flash mix temporarily to maintain this detention period if the plant is expected to be expanded in the near future.

c. Velocity gradient - The minimum shall be 300 (ft/sec)/ft.

4.1.3 Flocculation (Slow Mixing):

a. Basin Design - Inlet and outlet design shall prevent short circuiting and destruction of floc. A drain shall be provided.

b. Detention - The detention time for floc formation must be at least 30 minutes, with a detention time of 45 minutes being recommended.

c. Equipment - Agitators shall be driven by variable speed drives with the peripheral speed of paddles ranging from 0.5 to 2.0 ft/sec. The speed of each successive agitator should be less than the previous one.

d. Piping - Flocculation and sedimentation basins shall be as close together as possible. The velocity of flocculated water through pipes or conduits to settling basins shall be not less than 0.5 nor greater than 1.5 ft./sec. Allowances must be made to minimize turbulence at bends and changes in direction.

e. Other designs - Baffling may be used to provide for flocculation in small plants only after consultation with the Department. Minimum flow-through velocity shall be not less than 0.5 nor greater than 1.5 ft./sec. with a detention as noted above.

4.1.4 Sedimentation - Sedimentation shall follow flocculation. The detention time for effective clarification is dependent upon a number of factors related to basin design and the nature of the raw water. The number of basins required is dependent upon the turbidity, color and colloidal matter and taste and odor causing compounds to be removed.

a. Detention Time - Plants with conventional sedimentation shall provide a minimum of 4 hours of settling time, except for iron removal plants which shall have a minimum of 3 hours.

b. Depth - Should be based on an average depth of 8 ft. However, calculations using surface area, overflow rate and detention time should be used.

c. Rectangular tanks - A length to width ratio of 4:1 should be used.

d. Tube Settlers - Detention time required for sedimentation basins may be reduced to a minimum of 1 hour if tube settlers are installed. The maximum loading rate on the tube settlers shall be no greater than 2.5 gpm/ft2. Provisions shall be made for more frequent removal of sludge from the basins than is required for conventional sedimentation.

e. Plate Settlers – shall be designed, installed and loaded per the manufacturers recommendations.

f. Inlet Devices - Inlets shall be designed to distribute the water equally and at uniform velocities. Open ports, submerged ports, or similar entrance arrangements are required. A baffle should be constructed across the basin close to the inlet end and should project several feet below the water surface to dissipate inlet velocities and provide uniform flows across the basin. Velocity is not to exceed 0.25 ft/sec.

g. Surface overflow Rate - Shall be between 0.25 - 0.38 gpm/sq. ft. for conventional sedimentation. When tube settlers are used design of effluent weirs or pipes shall minimize carry over of floc from the tubes.

h. Velocity - The velocity through settling basins shall not exceed 0. 5 feet per minute. The basins must be designed to minimize short circuiting. Baffles must be provided as necessary. Not applicable if tube settlers are used.

i. Drainage - Basins must be provided with a means for dewatering. Basin bottoms should slope toward the drain not less than 1 foot in 12 feet where mechanical sludge collection equipment is not required. Drain lines shall be designed to empty the basin in 4 hours or less.

j. Weir Overflow Rate - An overflow weir should be installed which will establish the maximum water level desired on top of the filters. Adjustable V-notch weirs are preferred. Weir overflow rates shall be between 8 - 10 gpm/ft. for raw water with low turbidity and 10 - 15 gpm/ft. for raw water with high turbidity. It shall discharge with a free fall at a location where the discharge can be observed. Other methods will be considered when presented.

k. Safety - Permanent ladders or handholds should be provided for safety on the inside walls of basins above water level. Guard rails shall be included. Flushing lines or hydrants must not include interconnection of the potable water with non-potable water.

l. Sludge Collection - Mechanical sludge collection equipment should be provided.

m. Sludge Disposal - Facilities are required by the Department for disposal of sludge. See Section 4.11. Provision shall be made for operator to observe or sample sludge being withdrawn from unit.

4.1.5 Solids Contact Unit - Solids contact units are acceptable for clarification and/or softening. Clarifiers should be designed for the maximum uniform rate and should be adjustable to changes in flow which are less than the design rate and for changes in water characteristics. A minimum of 2 units is required. The following are design criteria for consideration, but any design shall be submitted in detail to be reviewed on a case-by-case basis.

a. Installation of equipment - Supervision by a representative of the manufacturer should be provided with regard to all mechanical equipment at the time of:

1. installation, and

2. initial operation.

b. Operating equipment - The following should be provided for plant operation:

1. a complete outfit of tools and accessories,

2. necessary laboratory equipment,

3. adequate piping with suitable sampling taps so located as to permit the collection of samples of water from critical portions of the units.

c. Chemical feed - Chemicals should be applied at such points and by such means as to insure satisfactory mixing of the chemicals with the water.

d. Mixing - Mixing devices employed should be so constructed as to:

1. provide good mixing of the raw water with previously formed sludge particles, and

2. prevent deposition of solids in the mixing zone.

e. Flocculation - Flocculation equipment should:

1. be adjustable,

2. provide for coagulation to occur in a separate chamber or baffled zone within the unit,

3. provide the flocculation and mixing period to be not less than 30 minutes.

f. Sludge concentrators - The equipment should provide either internal or external concentrators in order to obtain a concentrated sludge with a minimum of waste water.

g. Sludge removal - Sludge removal design should provide that:

1. sludge pipes shall be not less than three inches in diameter and so arranged as to facilitate cleaning,

2. entrance to sludge withdrawal piping shall prevent clogging,

3. valves shall be located outside the tank for accessibility,

4. operator may observe or sample sludge being withdrawn from the unit,

5. backflow from sanitary sewer systems be impossible.

h. Cross-connections:

1. blow-off outlets and drains should terminate and discharge at places satisfactory to the Department.

2. cross-connection control should be included for the potable water lines used to backflush sludge lines.

i. Detention period - Systems using a sludge blanket should have a minimum detention time of 1 hour with the flow rate not to exceed 1.0 gpm/ft2.

j. Suspended slurry concentrate - Units should be designed so that continuous slurry concentrates of 1% or more, by weight, can be satisfactorily maintained.

k. Water Losses

1. units should be provided with suitable controls for sludge withdrawal,

2. total water losses should not exceed:

(i) 5% for clarifiers,

(ii) 3% for softening units.

3. solids concentration of sludge bled to waste should be:

(i) 3% by weight for clarifiers,

(ii) 5% per cent by weight for softeners,

l. Weirs or orifices - The units should be equipped with either overflow weirs or orifices. Weirs shall be:

1. adjustable,

2. at least equivalent in length to the perimeter of the tank,

3. constructed so that surface water does not travel over 10 feet horizontally to the collection trough.

m. Weir loading - Should be same as conventional settling.

4.2 FILTRATION - Acceptable filters include, at the discretion of the Department, the following types:

a. gravity filters,

b. pressure filters.

The application of any one type must be supported by water quality data representing a reasonable period of time to characterize the variations in water quality. Experimental treatment studies may be required to demonstrate the applicability of the method of filtration proposed.

4.2.1 Gravity Filters

a. Number - At least two units shall be provided. Where declining rate filtration is provided, the variable aspect of filtration rates, and the number of filters must be considered when determining the design capacity for the filters.

b. Rate of Filtration

1. Standard Rate Filtration - The permissible rate of filtration shall be determined by the quality of the raw water, the degree of pretreatment provided, the filter media provided the quality of operation provided and other considerations required by the Department. The nominal rate shall be 2 gpm/ft2 of filter area for turbidity removal plants, and 3 gpm/ft2 of filter area for iron removal plants,

2. High Rate Filtration - Filtration rates for turbidity or iron removal plants of up to 4 gpm/ft^2 are acceptable with the following.

i. Mixing, flocculation, and sedimentation must meet the requirements of section 4.1.

ii. Dual or mixed filter media must be used.

iii. Additional instrumentation for coagulation control may be required for those plants with filter rates greater than 3 gpm/ft2. (Examples: raw and settled water continuous monitoring turbidimeters, pilot filter or zetameter.)

iiii. Filtration rates above 4 gpm/ft2 will be considered on a case-by-case basis with a trial period to demonstrate effective treatment at the increased rate.

c. Declining Rate Filtration - This is a design where no rate-of-flow controllers are installed. The rate of flow through the filter media is greatest when the media has just been back washed and gradually declines as the media becomes filled with contaminants.

1. The design must include means to insure that the water level during operation will not fall below the level of the top of the media.

2. The filtration rate must not exceed 6 gpm/ft2 when the filter is clean (immediately following back wash) and uses dual or mixed media.

3. This design is normally appropriate only when four or more filters are used in the plant.

d. Direct Filtration - will be considered on a case-by-case basis depending on the quality and variability of the source water. All filters shall have dual or mixed media. A flash mix shall be provided and flocculation basins may also be required.

e. Structural Details and Hydraulics - The filter structure shall be so designed as to provide for:

1. vertical walls within the filter, unless otherwise approved,

2. no protrusion of the filter walls into the filter media,

3. enclosure in a building,

4. head room to permit normal inspection and operation,

5. minimum depth of filter of 8-1/2 feet,

6. minimum water depth over the surface of the sand of 3 feet,

7. trapped effluent to prevent backflow of air to the bottom of the filters,

8. prevention of floor drainage to the filter with a minimum 4-inch curb around the filters,

9. prevention of flooding by providing overflow,

10. maximum velocity of treated water in pipe and conduits to filters of 2 fps,

11. minimal disturbance of the media from incoming water,

12. washwater drain capacity to carry maximum flow,

13. walkways around filters, to be not less than 24 inches wide,

14. no common wall between settling basins and filters.

f. Washwater Troughs - Washwater troughs shall be so designed to provide:

1. the bottom elevation above the maximum level of expanded media during washing,

2. the top elevation above the filter surface not to exceed 30 inches,

3. a 2-inch freeboard at the maximum rate of wash,

4. the top or edge to be level,

5. spacing so that each trough serves the same number of square feet of filter area,

6. maximum horizontal travel of suspended particles to reach trough not to exceed 3 feet.

g. Filter Material - installation of media shall be in accordance with current AWWA standards.

1. Sand - The media shall be clean silica sand having:

i. a depth of at least 30 inches,

ii. an effective size of from 0.35 mm to 0.55 mm, depending upon the quality of the raw water, and

iii. a uniformity coefficient not greater than 1.70.

2. Dual Media (Sand/Anthracite) - a combination of sand and clean crushed anthracite may be used. The anthracite shall have:

i. an effective size of 0.8 mm - 1.2 mm, and

ii. a uniformity coefficient not greater than 1.85.

iii. anthracite layer shall not exceed 20 inches in 30-inch bed.

iv. Granular activated carbon may be substituted for anthracite if approved by the Division of Water Supply

3. Mixed Media - To be approved by the Department.

4. A 3-inch layer of torpedo sand may be used as a supporting media for the filter sand; such torpedo sand shall have:

   i. an effective size of 0.8 mm to 2.0 mm, and,

   ii. a uniformity coefficient not greater than 1.7.

5. Gravel - Gravel, when used as the supporting media, shall consist of hard, rounded particles.

   i. The minimum gravel size of the bottom layer should be 3/4 inch or larger.

   ii. For proper grading of intermediate layers:

      (1) the minimum particle size of any layer should be as large as the maximum particle size in the layer next above and

      (2) within any layer the maximum particle size should not be more than twice the minimum particle size.

   iii. The depth of any gravel layer should not be less than 2 inches or less than twice the largest gravel size for that layer, whichever is greater. The bottom layer should be thick enough to cover underdrain laterals, strainers, or other irregularities in the filter bottom.

   iv. The total depth of gravel above the underdrains should not be less than 10 inches.

6. Reduction of gravel depths may be considered upon justification to the Department when proprietary filter bottoms are installed.

7. Media retention systems with no support gravel will be considered for approval on a case-by-case basis.

h. Filter Bottoms and Strainer Systems - Departures from these standards may be acceptable for high rate filters and for proprietary bottoms. Porous plate bottoms shall not be used. The design of manifold type collection systems shall be such as to:

   1. minimize loss of head in the manifold and laterals,

   2. assure even distribution of washwater and even rate of filtration over the entire area of the filter,

   3. provide the ratio of the area of the final openings of the strainer systems to the area of the filter at about 0.003,

4. provide the total cross-sectional area of the laterals at about twice the total area of the final openings,

5. provide the cross-sectional area of the manifold at l-1/2 to 2 times the total area of the laterals.

i. Surface Wash - Surface or subsurface wash facilities are required except for filters used exclusively for iron or manganese removal, and may be accomplished by a system of fixed nozzles or a revolving-type apparatus.

1. All surface wash devices shall be designed with:

   i. provisions for water pressures of 45 to 75 psi,

   ii. air vacuum relief valve or a reduced pressure backflow preventer if the surface wash supply is provided through a separate line from the high service line,

   iii. air wash can be considered based on experimental data and operating experiences.

j. Appurtenances - The following shall be provided for every filter:

1. sampling tap on the effluent line,

2. indicating loss-of-head gauge,

3. indicating flow-rate control; a modified rate controller which limits the rate of filtration to a maximum rate may be used,

4. provisions for draining the filter to waste with appropriate measures for backflow prevention (see Section 4.11.),

5. turbidimeter with recorder reading in NTU's on effluent line of each filter when raw water is from a surface source or ground source is in an area where turbidity may be a problem.

6. a 1 to l½ inch pressure hose and storage rack on the operating floor for washing filter walls. The hose connection shall be protected with a vacuum breaker.

k. Backwash - Provisions shall be made for washing filters as follows:

1. a rate to provide for a 50 percent expansion of the media is recommended; for a sand filter, a minimum rate of 18.75 gpm/ft2 is required, consistent with water temperatures and specific gravity of the filter media;

2. filtered water provided at the required backwash rate by washwater tanks, a washwater pump, from the high service main, or a combination of these;

3. washwater pumps in duplicate unless an alternate means of obtaining washwater is available,

4. water supply to back wash one filter for at least 15 minutes at the design rate of wash,

5. washwater regulator or valve on the main washwater line to obtain the desired rate of filter wash with the washwater valves on the individual filters open wide,

6. rate-of-flow indicator on the main washwater line, located so that it can be easily read by the operator during the washing process,

7. after washwater pumps are turned off and influent line is opened, a rewash cycle shall be performed for about 5 minutes during which water is filtered to the drain; piping must be provided for this purpose.

8. upon written request to this Department, if filter operation is automatic, the maximum permissible filter rate may be exceeded through remaining filters when one is being backwashed such that the plant flow would remain the same.

1. Miscellaneous - Roof drains shall not discharge into the filters or basins and conduits preceding the filters. All filters must be enclosed.

4.2.2 Pressure Filters - The use of these filters may be considered for iron and manganese removal and for turbidity removal from ground water sources. Pressure filters shall not be used in the filtration of surface waters or following lime soda softening.

a. General - Minimum criteria relative to number, rate of filtration, structural details and hydraulics, filter media, etc., provided for gravity filters also apply to pressure filters where appropriate.

b. Details of Design - The filters shall be designed to provide for:

1. head gauges on the inlet and outlet pipes of each filter,

2. an easily readable meter or flow indicator on each battery of filters; a flow indicator is recommended for each filtering unit,

3. filtration and backwashing of each filter individually with an arrangement of piping as simple as possible to accomplish these purposes,

4. minimum side wall shell height of 5 feet; a corresponding reduction in side wall height is acceptable where proprietary bottoms permit reduction of the gravel depth,

5. the top of the washwater collection trough to be at least 18 inches above the surface of media,

6. the underdrain system to collect efficiently the filtered water and to distribute the backwash water at a rate not less than 15 gpm/ft2 of filter area,

7. backwash flow indicators and controls that are easily readable while operating the control valves,

8. air release valve on the highest point of each filter,

9. accessible manhole to facilitate inspections and repairs,

10. means to observe the wastewater during backwashing,

11. construction to prevent cross-connection,

12. depth of filter media shall be the same as for gravity filters.

4.3 PACKAGE TREATMENT PLANTS, MEMBRANES AND OTHER TECHNOLOGIES - Will be reviewed on a case-by-case basis based on demonstrated performance criteria.

4.3.1 Package Treatment Plants – may be acceptable for source waters that are generally low in turbidity and do not experience large or frequent turbidity spikes. Filter backwash and clarifier flush/rinse frequencies along with water production efficiency must be considered for each application. Adequate detention times must be evaluated for oxidation processes, coagulation, TOC reduction and taste & odor control.

4.3.2 Membrane Filtration – is generally acceptable for turbidity/particulate removal. Each membrane module must have a continuous filtrate turbidity monitor and provisions for direct integrity testing. Other treatment processes such as coagulation, flocculation and oxidation must be used in conjunction with membranes where dissolved constituents such as TOC, iron and manganese are present in sufficient quantities to require treatment/removal. Clarification/sedimentation should be provided prior to membrane filtration where turbidity and suspended solids are very high in the raw water.

4.3.3 Cartridge and Bag Filters – will be considered for approval on a case-by-case basis depending on raw water quality and the size of the water system.

4.4 DISINFECTION - Chlorine is the preferred disinfecting agent. Other agents will be considered by the Department, provided reliable feeding equipment is available and testing procedures for a residual are recognized in "Standard Methods for the Examination of Water and Wastewater," latest edition. Continuous disinfection is recommended for all water supplies and is required at all community public water systems serving more than 50 connections or 150 persons.

4.4.1 Equipment

a. Type - Solution feed gas type chlorinator and hypochlorite feeders of the positive displacement type are acceptable (see Part 5). Alternative chlorine feeders such as tablet chlorinators may be considered for some applications.

b. Capacity - The chlorinator capacity shall be such that a free chlorine residual of at least 2 mg/L can be attained in the water after a contact time of at least 30 minutes when maximum flow rates coincide with anticipated maximum chlorine demands. The equipment shall be of such design that it will operate accurately over the desired feeding range.

c. Dual Chlorination - Two chlorinator shall be provided and operated simultaneously such that each feeds approximately half the chlorine requirement.

d. Spare Parts - Spare parts shall be provided so that either unit could be equipped to supply the entire chlorine requirement.

e. Automatic Switchover - Automatic switchover of chlorine cylinders should be provided where necessary to assure continuous disinfection. This does not take the place of having dual chlorination.

f. Automatic Proportioning - Automatic proportioning chlorinator will be required where the rate of flow either is not reasonably constant or where the quality of the water is subject to rapid changes.

4.4.2 Contact Time and Point of Application

a. Due consideration shall be given to the contact time of the chlorine in water with relation to pH, ammonia, taste producing substances, temperature, bacterial quality, trihalomethanes formation potential and other pertinent factors. Chlorine should be applied at a point which will provide adequate contact time. All basins used for disinfection must be designed to minimize short-circuiting.

b. At plants treating surface water, provisions should be made for applying chlorine to the raw water, top of filters, and filtered water.

c. At plants treating groundwater, provision should be made for applying chlorine to the clearwell inlet and the high lift pump suction.

d. Free residual (breakpoint) chlorination is required; 30 minutes contact time should be provided for ground waters and 2 hours for surface waters.

4.4.3 Chlorinator Piping

a. The water supply piping shall be designed to prevent contamination of the treated water supply by source of questionable quality.

b. Pipe material - The pipes carrying elemental liquid or dry gaseous chlorine under pressure and liquid chlorine must be schedule 80 seamless steel tubing or other materials recommended by the Chlorine Institute (never use PVC). Rubber, PVC, polyethylene, or other materials recommended by the Chlorine Institute must be used for chlorine solution piping and fittings. Nylon products are not acceptable for any part of the chlorine solution piping system.

c. Backflow Protection - All chlorine solution lines feeding into water having less than a full cycle of treatment (ahead of filters) shall be vented to the outside atmosphere. This venting shall be provided in such a manner that backflow into treated waters is prevented. Vacuum breakers and other mechanical devices shall not be substituted for a vent. Vents for chlorine lines shall:

1. be the same size as the solution line piping,

2. be connected to the solution line at a point where it is elevated a minimum of 6 feet above the maximum water level in the receiving basin,

3. have no shut off valves,

4. be extended to a high enough elevation outside the building that overflow from the vent tube during surges is prevented,

5. have a nylon or other suitable insert screen covering the vent which has been turned downward near its end,

6. not be subject to back pressures.

d. Distribution Panels - The Department recommends the use of chlorine solution distribution panels to ease the change of chlorine solution application points or the change of chlorine feed equipment. If a distribution panel is installed all chlorine solution lines except those feeding into the clear well or filter effluent must be vented as specified in section 4.4.3c. This venting is to be located between the distribution panel discharge and the point of application. Where chlorine solution from one chlorine feed unit is to be split to feed at more than one application point, a suitable rotameter shall be installed to allow accurate proportioning of the total flow among the application points.

4.4.4 Housing - Adequate housing must be provided for the chlorination equipment and for storing the chlorine supply (See Section 5.3).

4.4.5 Chlorine Dioxide – may be used for oxidation, disinfection and/or treatment of tastes and odors. Chlorine dioxide may be considered in conjunction with other treatment processes for meeting surface water treatment requirements or as an alternative to raw water chlorination where disinfection by-products must be reduced. Water systems that add chlorine dioxide must monitor for chlorine dioxide residual and chlorite.

4.4.6 UV Light - may be used for disinfection at water treatment plants in conjunction with chlorination and other treatment processes to meet surface water treatment requirements. UV light may also be used at groundwater treatment plants. Water systems using UV light must also provide chlorination for residual disinfection.

4.4.7 Ozone – may be used at water treatment plants for oxidation, disinfection, and meeting surface water treatment requirements. Water systems using ozone must monitor for bromate.

4.4.8 Hydrogen Peroxide – may be used at water treatment plants for raw water oxidation and/or disinfection. Hydrogen peroxide may be used to replace raw water chlorination where disinfection by-products must be reduced.

4.4.9 Permanganates – potassium permanganate or sodium permanganate may be used for raw water oxidation and/or disinfection. Permanganates may be used to replace raw water chlorination where disinfection by-products must be reduced.

4.4.10 Chloramines – will be considered for use in water distribution systems if other methods to reduce disinfection by-products have failed to achieve compliance. Effects of chloramination on water chemistry, corrosivity and microbiological water quality must be evaluated.

4. 5 SOFTENING - In all but a very few locations in Tennessee softening of available raw water is not needed. Unless there is a demonstrated need, softening should be avoided because of the additional expense and because of the increased sodium content of the water when ion exchange softening is used.

4.5.1 Lime-Soda Process - The applicable design standards for mixing, flocculation and sedimentation are the same for the lime-soda process as for conventional clarification. Where softening is included as a treatment process in conjunction with clarification, the clarification criteria shall govern(see sections 4.1.2, 4.1.3 and 4.1.4). For criteria pertaining to softening with solids contact units see section 4.1.5.

a. Aeration - Determinations should be made for the C02 content of the raw water. When concentrations exceed 10 mg/L, the economics of removal by aeration as opposed to removal with lime should be considered (See Section 4.6).

b. Stabilization - Equipment for stabilization of water softened by the lime-soda process is required.

c. Sludge Collection - Mechanical sludge removal equipment shall be provided in the sedimentation basin (see section 4.11 for sludge disposal).

d. Sludge Disposal - Provisions must be included for proper disposal of softening sludges(See Section 4.11).

e. Disinfection - The use of excess lime shall not be considered an acceptable substitution for chlorination or any other approved method of disinfection (See Section 4.4).

4.5.2 Cation Exchange Process - Iron, manganese, or a combination of the two, in the oxidized state or unoxidized state, should not exceed 0.3 mg/L in the water as applied to the ion exchange resin. Pretreatment is required when the content of iron, manganese, or a combination of the two, is 1 mg/L or more.

a. Design - The units may be of pressure or gravity type, using automatic or manual regeneration. Automatic regeneration is suggested for small plants.

b. Exchange Capacity - The design capacity for hardness removal should not exceed 20,000 grains per cubic foot when resin is regenerated with 0.3 pounds of salt per kilogram of hardness removed..

c. Depth of Media - The depth of the exchange material should not be less than 3 feet.

d. Flow Rates - the rate of softening should not exceed 7 gallons per square foot per minute and the backwash rate should be 6 to 8 gallons per square foot per minute. Rate-of-flow controllers or the equivalent must be installed for the above purposes.

e. Freeboard - The freeboard will depend upon the specific gravity of the media. Generally, the washwater collector should be 24 inches above the top of the media.

f. Underdrains and Supporting Gravel - The bottoms strainer systems, and support for the exchange material shall conform to criteria provided for rapid rate gravity filters (See Sections 4.2.lg and 4.2.1h).

g. Brine Distribution - Facilities should be included for even distribution of the brine over the entire surface.

h. Cross Connection Control - Backwash, rinse and air relief discharge pipes should be installed in such a manner as to prevent any possibility of back-siphonage.

i. Bypass - A bypass shall be provided around softening units to produce a blended water of desirable hardness. Meters should be installed on the bypass line and on each softener unit. An automatic proportioning or regulating device and shut-off valve should be provided on the bypass line. In some installations it may be necessary to treat the bypassed water to obtain acceptable levels of iron and/or manganese in the finished water.

j. Additional Limitations - Waters having 1.0 units or more turbidity should not be applied directly to the cation exchange softener. Silica gel materials should not be used for waters having a pH above 8.4 or containing less than 6 mg/L silica and should not be used when iron is present. The cation exchange material shall be a type that is not damaged by residual chlorine. Phenolic resin should not be used.

k. Sampling Taps - Smooth-nose sampling taps must be provided for the collection of representative samples for both bacteriological and chemical analyses. The taps shall be located to provide for sampling of the softener influent, softener effluent, and the blended water. The sampling taps for the blended water shall be at least 20 feet downstream from the point of blending. Petcocks are not acceptable as sampling taps. Sampling taps should be provided on the brine tank discharge piping.

1. Brine and Salt Storage Tanks

1. Salt dissolving or brine tanks and wet storage tanks must be covered and must be corrosion resistant.

2. The make-up water inlet must be protected from back siphonage. Water for filling the tank should be distributed over the entire surface by pipes above the maximum brine level in the tank. The tanks should be provided with an automatic declining level control system on the make-up water line.

3. Wet salt storage basins must be equipped with manholes or hatchways for access and for direct dumping of salt from truck or railcar. Openings must be provided with raised curbs and watertight covers having overlapping edges similar to those required for finished water reservoirs.

4. Overflows, where provided, must be turned down, have a proper free fall discharge and be protected with corrosion resistant screens or self-closing flap valves.

5. Two wet salt storage tanks or compartments designed to operate independently should be provided.

6. The salt is to be supported on graduated layers of gravel under which is a suitable means of collecting the brine.

7. Alternative designs which are conducive to frequent cleaning of the wet salt storage tank may be considered.

m. Storage Capacity - Salt storage basins should have sufficient capacity to store in excess of l-1/2 carloads or truckloads of salt, and to provide for at least 30 days of operation.

n. Stabilization - Stabilization for corrosion control shall be provided (See Section 4.9).

o. Waste Disposal - Suitable disposal must be provided for brine waste (See Section 4.11).

p. Construction Material - Pipes and contact materials must be resistant to the aggressiveness of salt. Plastic and red brass are acceptable piping material. Steel and concrete must be coated with a non-leaching protective coating which is compatible with salt and brine.

q. Housing - Salt Storage tanks and feed equipment should be enclosed and separated from other operating areas in order to prevent damage to equipment.

4.6 AERATION - Aeration treatment devices as described herein may be used for oxidation, separation of gases or for taste and odor control.

4.6.1 Natural Draft Aeration - Design should provide that:

a. water is distributed uniformly over the top tray,

b. water is discharged through a series of three or more trays with separation of trays not less than 12 inches,

c. trays are loaded at a maximum rate of 20 gpm for each square foot of the top tray area,

d. trays have heavy wire mesh or perforated bottoms,

e. perforations are 3/16 to 1/2 inches in diameter, spaced 1 to 3 inches on centers, when perforations are used,

f. 8 to 12 inches of inert media are used, such as coke or limestone, that will not disintegrate due to freezing cycles,

g. aerated water receives disinfection treatment,

h. sufficient trays to reduce carbon dioxide to 10-15 mg/L,

i. location to take advantage of prevailing wind direction.

4.6.2 Forced or Induced Draft Aeration - Devices shall be designed to:

a. provide adequate countercurrent of air through enclosed aeration column,

b. be insect proof and lightproof,

c. be such that air introduced into column shall be screened through insect tight screen and be as free of dust as possible,

d. insure that water outlet is adequately sealed to prevent unwanted loss of air,

e. be such that sections of the aerator can be easily reached and removed for maintenance.

4.6.3 Other Methods of Aeration - Other methods of aeration may be used if applicable to the treatment needs. Such methods include but are not restricted to spraying, diffused air and mechanical aeration. The treatment processes must be designed to meet the particular needs of the water to be treated and are subject to the approval of the Department.

4.6.4 Wind Protection - Aerators that discharge through the atmosphere should be protected by being placed in a louvered enclosure so designed as to provide easy access to the interior.

4.6.5 Protection from Contamination - Aerators that are used for oxidation or removal of dissolved gases from waters that will be given no further treatment other than chlorination shall be protected from contamination from insects and birds.

4.6.6 Bypass - A bypass shall be provided for all aeration units.

4.6.7 Corrosion Control - The aggressiveness of the water after aeration should be determined and corrected by additional treatment, if necessary (See Section 4.9).

4. 7 IRON AND MANGANESE CONTROL - Iron and manganese control, as used herein, refers solely to treatment processes designed specifically for this purpose. The treatment process used will depend upon the character of the raw water. The selection of one or more treatment processes must meet specific local conditions as determined by engineering investigations, including chemical analysis of representative samples of water to be treated, and receive the approval of the Department. It may be necessary to operate a pilot plant in order to gather all information pertinent to the design.

4.7.1 Removal by Oxidation, Detention and Filtration.

a. Oxidation - Oxidation may be by aeration, as indicated in Section 4.6, or by chemical oxidation with chlorine or potassium permanganate.

b. Detention - A minimum detention of 20 minutes shall be provided following oxidation by aeration in order to insure that the oxidation reactions are as complete as possible. The detention basin shall be designed as a holding tank with no provisions for sludge collection but with sufficient baffling to prevent short circuits. Sedimentation basins should be provided when treating water with high iron and/or manganese content or where chemical coagulation is used to reduce the load on the filters.

c. Filtration - Filters shall conform to Section 4.2, except nominal rate shall not exceed 3 gpm/ft2 of filter area.

4.7.2 Removal by Lime-Soda Process - See Section 4.5.1.

4.7.3 Removal by Units Using Continuous Potassium Permanganate "Regeneration" - This process, consisting of a continuous feed of potassium permanganate to the influent of a manganese green-sand filter, is more applicable to the removal of manganese than to the removal of iron, due to economic considerations. The following apply:

a. The permanganate should be applied as far ahead of the filter as practical.

b. other oxidizing agents or processes such as chlorination or aeration may be used prior to the permanganate feed to reduce the cost of the chemical.

c. Anthracite media cap of at least six inches shall be provided over manganese treated greensand.

d. Normal filtration rate is 3 gpm/ft2.

e. Normal wash rate is 8 to 10 gpm/ft2.

f. Air washing should be provided.

g. Sample taps should be provided:

1. prior to application of permanganate,

2. immediately ahead of filtration,

3. at point between anthracite coal media and the manganese treated greensand,

4. halfway down the manganese treated greensand,

5. at the filter effluent.

4.7.4 Sequestration by polyphosphates - This process is only suitable only for concentrations of iron and manganese that are below the respective MCL’s. The dosage should not exceed 10 mg/L. Where phosphate treatment is used, satisfactory chlorine residuals should be maintained in the distribution system.

a. Feeding equipment shall conform to requirements of Part 5.

b. Stock phosphate solution must be kept covered and disinfected by carrying approximately 10 mg/L chlorine residual.

c. The point of application should be prior to any aeration or oxidation if no iron or manganese removal treatment is provided.

d. Phosphate chemicals must be food grade and meet or exceed AWWA Specifications.

4.7.5 Sampling Equipment - Smooth-nosed sampling taps shall be provided for control purposes. Taps shall be located on each raw water source, each treatment unit influent and each treatment unit effluent.

4.7.6 Testing Equipment - Testing equipment shall be provided for all plants. The equipment should have the capacity to accurately measure the iron content to a minimum of 0.1 mg/L and the manganese content to 0.05 mg/L.

4.8 FLUORIDATION - Commercial sodium fluoride, sodium silicofluoride and hydrofluosilicic acid shall conform to the applicable AWWA Standards. Other chemicals which may be made available must be approved by the Department.

4.8.1 Fluoride Compound Storage - Compounds shall be stored in covered or unopened shipping containers. Bulk storage units and day tanks, including carboys and drums in use for hydrofluosilicic acid, shall be vented to the atmosphere at a point outside any building.

4.8.2 Dry Conveyers - Provision must be made for the proper transfer of dry fluoride compounds from shipping containers to storage bins or hoppers, in such a way as to minimize the quantity of fluoride dust.

4.8.3 Chemical Feed Installations

a. shall conform to Part 5,

b. shall provide scales or loss-of-weight recorders for dry or acid chemical feeds. Dry volumetric feeders are to have percent-of-cycle timer or variable speed SCR drive. A minimum of 35-gallon dissolver with mechanical agitation,

c. shall have an accuracy that actual feed will be within 5% of that intended,

d. shall be such that the point of application of hydrofluosilicic acid, if into a pipe, shall be in the lower third of the pipe and project upward,

e. downflow saturators are not acceptable,

f. shall provide adequate anti-siphon devices for all fluoride feed lines,

g. piping from bulk storage to day tank should be schedule 80 PVC.

4.8.4 Protective Equipment - Suitable protective equipment shall be provided.

4.8.5 Dust Control Equipment - Suitable equipment shall be provided for wet-mopping and hosing dust that might accumulate in the plant.

4.8.6 Testing Equipment - Equipment shall be provided for measuring the quantity of fluoride ion in the water. Such equipment shall be subject to the approval of the Department.

4.9 CORROSION CONTROL - corrosion is caused by a reaction between the pipe material and the water in direct contact with each other. Consequently, there are three basic approaches to corrosion control:

a. Using pipe materials and designing the system so it is not corroded by a given water,

b. Modifying the water quality so it is not corrosive to the pipe material,

c. Placing a protective barrier or lining between the water and the pipe.

4.9.1 System design

a. Choose compatible materials throughout system where possible to avoid forming galvanic cells,

b. Avoid dead ends and stagnant areas,

c. Reduce mechanical stress, sharp turns and elbows,

d. Provide adequate insulation and avoid uneven heat distribution,

e. Eliminate grounding of electrical circuits to system.

4.9.2 Cathodic Protection - Metal tanks and reservoirs should be considered for protection from corrosion by this method.

4.9.3 Modification of Water Quality

a. pH adjustment by addition of lime, caustic soda or soda ash, in order to stabilize the water with regard to calcium carbonate.

b. Control of oxygen. Advantages of aeration for iron, H2S Or C02 removal should be balanced against the fact that dissolved oxygen is a corrosive agent.

4.9.4 Use of inhibitors. These may be used as appropriate.

a. Addition of lime or alkalinity increases the tendency of water to deposit CaCO3 forming a protective coating inside of pipe.

b. Inorganic phosphorus. Care is needed to select a chemical which not only masks the symptoms, but also reduces corrosion. (Sodium hexametaphosphate in low dosages of 2-4 mg/L only masks the symptoms while corrosion continues). Recent developments indicate the addition of zinc with a phosphate is effective in both inhibiting corrosion and controlling red water.

c. Sodium silicate. Effective in water with low hardness, alkalinity and pH less than 8.4 under relatively high velocity conditions.

4.9.5 Coatings and linings - Metal distribution system components' surfaces in contact with water shall be protected by being coated or lined.

a. Pipe linings include coal tar enamels, epoxy paint, and cement mortar.

b. Storage tanks are protected by such coatings as coal tar enamels, paints, vinyls, and epoxy.

4.10 TASTE AND ODOR CONTROL

4.10.1 Chlorination - Chlorination can be used for the removal of some objectionable odors. Adequate contact time must be provided to complete the chemical reactions involved.

4.10.2 Chlorine Dioxide - Chlorine dioxide has been generally recognized as a treatment for tastes caused by industrial wastes, such as phenols; however, chlorine dioxide can be used in the treatment of any taste or odor that is treatable by an oxidizing compound. Provision shall be made for proper storing and handling of sodium chlorite, so as to eliminate any danger of explosion (See Part 5).

4.10.3 Powdered Activated Carbon

a. Powdered activated carbon may be added prior to coagulation to provide maximum contact time, although facilities to allow the addition at several points is preferred, but not near the point of chlorine application.

b. The carbon can be added as a pre-mixed slurry or by means of a dry-feed machine as long as the carbon is properly "wetted".

c. Agitation is necessary to keep the carbon from depositing in the mixing chamber.

d. Provision shall be made for adequate dust control.

e. The required dosage of carbon in a water treatment plant depends upon the tastes and/or odors involved, but provision shall be made for adding 0 mg/L to at least 40 mg/L.

f. Powdered activated carbon shall be handled as a potentially combustible material. It should be stored in a building or compartment as nearly fireproof as possible. Other chemicals should not be stored in the same compartment. Carbon feeder rooms should be equipped with explosion-proof electrical outlets, lights and motors.

4.10.4 Granular Activated Carbon Adsorption Units - Granular activated carbon units shall not be used in place of filters described in Section 4.2. Rates of flow shall be consistent with the type and intensity of the problem. The design used must be supported by the results of pilot plant studies when granular activated carbon units are used for organic removal.

4.10.5 Copper Sulfate and Other Copper Compounds - Continuous or periodic treatment of water with copper compounds to kill algae or other growths shall be controlled to prevent copper in excess of 1.0 mg/L as copper in the plant effluent or distribution system. Care shall be taken in obtaining a uniform distribution:

a. if alkalinity is less than 50 mg/L, dose at 0.9 lb/acre foot,

b. if alkalinity is greater than 50 mg/L, dose at 5.4 lb/acre foot.

4.10.6 Aeration - See Section 4.6.

4.10.7 Potassium Permanganate - Application of potassium permanganate may be considered provided the point of application is prior to filtration.

4.10.8 Ozone - Ozonation can be used as a means of taste and odor control. Adequate contact time must be provided to complete the chemical reactions involved. Ozone is generally more desirable for treating water with high threshold odors.

4.10.9 Other Methods - The decision to use any other methods of taste and odor control should be made only after careful laboratory tests and on consultation with the Department.

4.10.10 Flexibility - Plants treating water that is known to have taste and odor problems should be provided with equipment that makes several of the control processes available so that the operator will have flexibility in operation.

4.11 WASTE DISPOSAL - Provisions must be made for proper disposal of water treatment plant waste such as sanitary, laboratory, clarification, softening and ion sludges, filter backwash, and brines. The quantity of waste produced in water treatment shall be minimized by choice of treatment processes and chemicals. If supernatant water from backwash/sludge holding tanks or lagoons is to be recycled through the treatment plant, potential impacts on the treatment process must be considered. Recycled water must be returned to the head of the treatment plant or to an alternate location approved by the Division of Water Supply. Recycled water should be settled/clarified to reduce contaminants that may be concentrated in sludges and backwash water.

4.11.1 Waste Water and Sludge - The following means of waste and sludge disposal may be considered:

a. Lagoons - Design should provide:

1. location free from flooding,

2. when necessary, dikes, deflecting gutters, or other means of diverting surface water,

3. a minimum usable depth of 4 to 5 feet with adequate freeboard,

4. 3 to 5 years solids storage volume,

5. multiple cells,

6. adjustable decanting devices,

7. convenient cleaning,

8. effluent sampling point,

9. adequate safety provisions.

b. Sludge Beds - Beds for lime softening sludges should provide for an application of slurry of at least 12 inches. Multiple beds should be provided so designed as to permit a minimum of one year's total storage. The storage capacity should be based on assumption that for each part per million of hardness removed there will be two parts per million of dry solids, and the accumulated sludge density being 120 pounds per cubic foot. Distribution channels are required for spreading sludge over the entire area. Provisions must be made for easy access and for paved loading ramps and underdrains. See Section 4.11.1.1 for provisions on flooding and surface water diversion.

c. Disposal to Sanitary Sewer System

1. Approval must be obtained from sewer system officials.

2. Consideration shall be given to the effects the water plant waste will have at the sewer plant including:

i. effect on the sewage treatment process,

ii. additional sludge to be handled.

3. Consideration shall be given to the effects of disposal into the sewage collection system. A schedule for disposal shall be determined in conjunction with sewer system officials.

d. other methods - These include holding tanks, vacuum filters, centrifuging, and recalcining. Detailed studies should be made to justify their use.

4.11.2 Sanitary Waste - The sanitary waste from water treatment plants, pumping stations, etc., must receive treatment. Waste from these facilities must be discharged either directly to a sanitary sewer system or to an individual waste disposal facility providing suitable treatment.

Part 5 - CHEMICAL APPLICATION

5.0 GENERAL - Plans and specifications describing water treatment plants (new, modified or expanded) shall include the chemicals and chemical feed equipment to be used in the treatment process.

5.0.1 These plans and specifications shall include:

a. descriptions of feed equipment, including maximum and minimum feed ranges,

b. location of feeders, piping layout and points of application,

c. storage and handling facilities,

d. specifications for chemicals to be used,

e. operating and control procedures,

f. descriptions of testing equipment and procedures.

5.0.2 Chemical shall be applied to the water at such points and by such means as to:

a. provide maximum flexibility of operation through various points of application, when appropriate, and

b. prevent backflow at all points of feed.

5.1 FEED EQUIPMENT

5.1.1 Number of Feeders

a. Where chemical feed is essential to the production of safe drinking water or necessary for continuous operation

1. a minimum of two feeders shall be provided,

2. a standby unit or combination of units of sufficient capacity should be available to replace the largest unit during shut-downs.

b. Spare parts shall be available for all feeders to replace parts which are subject to wear and damage.

5.1.2 Design and Capacity - Design and capacity shall be such that:

a. feeders will be able to supply, at all times, the necessary amounts of chemical at an accurate rate, throughout the range of feed;

b. feeders are adjustable to handle all plant flow rates;

c positive displacement type solution feed pumps shall be used to feed liquid chemicals, and shall not be used to feed chemical slurries;

d. chemical solutions cannot be siphoned into the water supply;

e. service water supply cannot be contaminated by chemical solutions by:

1. equipping the supply line with backflow prevention devices (see Section 5.l.8.c), or

2. providing an air gap between supply line and solution tank.

f. chemical-contact materials and surfaces are resistant to the aggressiveness of the chemical solution;

g. dry chemical feeders will:

1. measure chemicals volumetrically or gravimetrically,

2. provide effective solution of the chemical in the solution pot,

3. provide gravity feed from solution pots, in open troughs when feasible,

4. completely enclose chemicals to prevent emission of dust to any of the operating areas (see Section 5.2.3d).

h. no direct connection exists between any sewer and a drain or overflow from the feeder or solution chamber or tank.

5.1.3 Location - chemical feed equipment

a. shall be conveniently located near points of application to minimize length of feed lines;

b. shall be readily accessible for

1. servicing, repair and calibration, and

2. observation of operation;

c. shall be located and protective curbing provided, so that chemicals from equipment failure, spillage or accidental drainage shall not enter the water through conduits, treatment or storage basins, or result in hazardous discharge.

5.1.4 Control

a. Feeders may be manually or automatically controlled, with automatic control reverting to manual control as necessary.

b. Process must be manually started following shutdown, unless otherwise approved by the Department.

c. Feed rates proportional to flow must be provided.

d. Automatic chemical dose or residual analyzers may be approved for use and must provide

1. alarms for critical values, and

2. recording charts.

5.1.5 Solution Tanks

a. Means shall be provided in a solution tank to maintain uniform strength of solution, consistent with the nature of the chemical solution; continuous agitation is necessary to maintain slurries in suspension.

b. Two solution tanks may be required for a chemical, of specific capacity, to assure continuity of supply in servicing a solution tank.

c. Each tank shall be provided with a drain;

   1. No direct connection between any tank or drain and a sewer shall be permitted, and

   2. Any drain must terminate at least two pipe diameters above the overflow rim of a receiving sump, conduit or waste receptacle.

d. Means shall be provided to indicate the solution level in the tank.

e. Make-up water shall enter the tank from above the maximum solution level, providing an air gap of two pipe diameters but not less than six inches, or shall be protected with an approved backflow prevention devices (see Section 5.1.8.c).

f. Chemical solutions shall be kept covered. Large tanks with access openings shall have such openings curbed and fitted with tight covers.

g. Subsurface locations for solution tanks shall:

   1. be free from sources of possible contamination.

   2. assure positive drainage for ground waters, accumulated water, chemical spills and overflows.

h. Overflow pipes, when provided, should:

   1. be turned downward, with end screened.

   2. have free discharge, and

   3. be located where noticeable.

5.1.6 Weighing Scales

a. shall be provided for weighing cylinders, at all plants utilizing chlorine gas; for large plants, indicating and recording type are desirable;

b. shall be provided to measure the amount of fluoride fed with the exception of the use of a saturator, which shall have a water meter;

c. should be provided for volumetric dry chemical feeders;

d. should be accurate to measure increments of 0.5% of load;

5.1.7 Feed Lines

a. should be as short as possible in length of run, and

d. Special precautions must be taken with:

1. sodium chlorite, to eliminate any danger of explosion;

2. activated carbon, which is a potentially combustible material, requiring isolated, fireproof storage and explosion-proof electrical outlets, lights and motors in areas of dry handling.

3. calcium hypochlorite and potassium permanganate, which may ignite spontaneously on contact with combustible substances;

4. hydrofluosilicic acid, which is extremely corrosive. Fumes or spillage may damage equipment or structures.

5. liquid caustic (50% sodium hydroxide solution) which is hazardous and may be lost from solution at low temperature.

6. gaseous chlorine (see Sections 5.3.4-5.4).

7. on-site generation of sodium hypochlorite. Provisions must be included for dilution and venting of potentially explosive hydrogen gas.

e. Chemicals shall be stored in covered or unopened shipping containers, unless the chemical is transferred into an approved covered storage unit.

f. Solution storage or day tanks supplying feeders directly should have sufficient capacity for one day of operation.

g. Acid storage tanks must be vented to the outside atmosphere, but not through vents in common with day tanks.

5.2.3 Handling

a. Provisions shall be made for

1. measuring quantities of chemicals used to prepare feed solutions, and

2. for easy calibration of solution pumps measured from the suction side.

b. Storage tanks and pipelines for liquid chemicals shall be specific to the chemicals and not for alternates.

c. Chemicals that are incompatible shall not be fed, stored or handled together.

d. Provisions must be made for the proper transfer of dry chemicals from shipping containers to storage bins or hoppers, in such a way as to minimize the quantity of dust which may enter the room in which the equipment is installed; control should be provided by use of:

1. vacuum pneumatic equipment or closed conveyer systems, or

2. facilities for emptying shipping containers in special enclosures, or

3. exhaust fans and dust filters which put the hoppers or bins under negative pressure.

e. Precautions shall be taken with electrical equipment to prevent explosions, particularly in the use of sodium chlorite and activated carbon.

f. Acids shall:

1. be kept in closed, acid-resistant shipping containers or storage units;

2. not be handled in open vessels, but should be pumped in undiluted form from original containers, through suitable hose, to the point of treatment or to a covered day tank.

g. Carts, elevators and other appropriate means shall be provided for lifting chemical containers to minimize excessive lifting by operators.

h. Provisions shall be made for disposing of empty bags, drums or barrels, by approved procedures which will minimize exposure to dusts.

5.3 HOUSING

5.3.1 Structures, rooms and areas accommodating chemical feed equipment shall provide convenient access for

a. servicing and repair,

b. observation of operation.

5.3.2 Floor surfaces shall be smooth and impervious, slip-proof and well-drained with 2.5% slope, minimum.

5.3.3 open basins, tanks and conduits shall be protected from chemical spills or accidental drainage.

5.3.4 Chlorine gas feed and storage shall be:

a. enclosed and separated from other operating areas in order to prevent injury to personnel and damage to equipment; separate chlorine feed and storage rooms may be required for large installations;

b. provided with an inspection window to permit viewing of the interior of the room and the equipment;

c. provided with doors opening outward with a crash bar, assuring ready means of exit; doors opening to the building exterior only shall be provided.

d. provided with locks to prevent general public access.

5.3.5 Where chlorine gas is used, ventilation for each room shall be provided for one complete air change per minute; and

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;

b. air inlets shall be through louvers near the ceiling, and temperature controlled to prevent adverse affect on chlorinator;

c. switches for fans and lights shall be outside of the room, at the entrance; signal light indicating fan operation shall be provided at each entrance when fan can be controlled from more than one point;

d. vents from feeders and storage shall discharge to the outside atmosphere, above grade.

5.3.6 Chlorinator rooms should be heated to 60 degrees F, but should be protected from excess heat; cylinders and gas lines should be protected from temperatures above that of the feed equipment.

5.3.7 Gaseous feed chlorine installations shall be equipped with a gas detection device connected to an audible alarm to prevent undetected, potentially dangerous leakage of chlorine gas.

5.4 OPERATOR SAFETY

a. Gases from feeders, storage and equipment exhausts shall be conveyed to the outside atmosphere, above grade and remote from air intakes.

b. Special provisions shall be made for ventilation of chlorine feed and storage rooms (see Section 5.3.5).

c. A M-S-A air mask, Model 401, Catalog No. 01-95066 or equal, complete with storage cabinet and 30 minute air cylinder shall be provided along with a 30 minute backup cylinder to prevent loss of utility while the primary air cylinder is being refilled or tested. The air mask shall be cabinet-mounted close by but not inside the chlorine room, and shall be easily accessible to the operator.

d. A bottle of ammonium hydroxide shall be available for chlorine leak detection during cylinder change.

e. All gaseous feed chlorine installations shall be equipped with appropriate leak repair kits.

f. At least one pair of rubber gloves with long gauntlets, a dust respirator of a type approved by the U.S. Bureau of Mines for toxic dusts, and an apron or other protective clothing shall be provided for each operator in any shift who will handle dry chemicals.

g. Rubber gloves with long gauntlets, rubber roots, goggles, rubber apron or other suitable protective clothing shall be provided for each operator preparing chemical solutions, or cleaning up spills.

h. Facilities shall be provided for washing of face, gloves and protective equipment.

i. A safety shower shall be provided in areas where hazardous chemicals are handled.

j. On-site generation of sodium hypochlorite must include dilution and venting of hydrogen gas.

Part 6 - LABORATORY FACILITIES

6.0 GENERAL - Laboratory equipment and facilities shall be compatible with the raw water source, intended design of the treatment plant, and the complexity of the treatment process involved. Recognized laboratory procedures must be utilized. See Parts 4 and 5 for related criteria.

6.1 EQUIPMENT – Laboratory and analytical equipment shall be provided to conduct all daily water quality testing as specified by the Department.

6.2 LABORATORY SPACE AND FACILITIES

6.2.1 Laboratory facilities shall be located in a separate room from office/lunch activities and from the treatment units. Facilities shall be isolated by doors and not be located in the main traffic pattern.

6.2.2 Sufficient bench space, adequate ventilation, adequate lighting, storage room, laboratory sink, and auxiliary facilities shall be provided.

6.2.3 The bacteriological laboratory, if provided, shall have about 6-10 feet of counter space and shall be located in a separate room or area.

6.3 SAMPLE TAPS - Sample taps shall be provided so that water samples can be obtained from each water source and from appropriate locations in each unit operation of treatment. Taps shall be consistent with sampling needs and not be of petcock type. Sample lines and pumps where applicable shall be sized to minimize time lag between point of sampling and point of sample collection.

Part 7 - PUMPING FACILITIES

7.0 GENERAL - Pumping facilities shall be designed to maintain the sanitary quality of pumped water. Subsurface pits or pump rooms and inaccessible installations should be avoided. No pumping station shall be subject to flooding.

7.1 LOCATION - The pumping station shall be so located that the proposed site will meet the requirements of the sanitary protection of the water quality, hydraulics of the system and be protected against interruption of service by fire, flood or any other hazard.

7.1.1 Site Protection - The station shall be:

a. elevated to a minimum of one foot above the 100-year flood elevation, or protected to such elevation;

b. accessible at all times unless permitted to be out of service for period of inaccessibility;

c. graded around station so as to lead surface drainage away from the station;

d. protected to prevent vandalism and entrance by unauthorized persons or animals.

7.2 GROUND WATER FACILITIES - Where pumping facilities are used, wells and springs shall be vented by properly hooded and screened pipe extending at least 12 inches above the pump floor. Where necessary, provision shall be made for lubricating the pump from a point at least 6 inches above the top of the well cover, by means which will prevent contamination of the water supply.

7.2.1 Drilled Wells - Pumping stations located over drilled wells shall;

a. have riser pipe or casing extending at least 6 inches, and preferably 12 inches, above the floor, and be equipped with flange or suitable stuffing box;

b. have riser pipe or casing firmly connected to the pump structure to provide a water tight connection.

c. have base of pump not less than 6 inches above pump room floor;

d. have pump foundation and base designed to prevent water from coming into contact with the joint.

7.2.2 Submersible Pumps - Where a submersible pump is used, the top of the casing shall be effectively sealed against entrance of water under all conditions of vibration or movements of conductors or cables.

7.2.3 Discharge Piping - Discharge piping should be provided with means to pump to waste but shall not be directly connected to a sewer. The discharge line shall:

a. have control valves located above pump floor;

b. be protected against freezing;

c. be valved to permit testing and control of each well;

d. have watertight joints;

e. have all exposed valves protected.

7.3 SURFACE WATER FACILITIES - Pump stations normally associated with surface water sources, either as raw or finished water pump stations, shall:

a. have adequate space for the installation of additional units if needed, and for the safe servicing of all equipment;

b. be of durable character, fire and weather resistant and with outward opening doors;

c. have floor elevation of at least 6 inches above finished grade;

d. have underground structure waterproofed;

e. have all floors drained without impairing the quality of water being handled and if equipment is contained on the floor, the floor shall have sufficient slope to drain adequately.

f. provide suitable outlet for drainage from-pump glands without discharging onto the floor.

7.3.1 Suction Well - Suction wells shall:

a. be watertight;

b. have floors sloped to permit removal of water and entrained solids;

c. be covered or otherwise protected against contamination; including pump lubricant.

7.3.2 Equipment Servicing - Pump facilities shall be provided with;

a. crane-ways, hoist beams, eye bolts, or other adequate facilities for servicing or removal of pumps, meters or heavy equipment;

b. openings in floors, roofs or wherever else needed for removal of heavy or bulky equipment;

c. a convenient tool board or other facilities as needed for proper maintenance of the equipment.

7.3.3 Stairways and Ladders - Stairways or ladder shall

a. be provided between all floors, in pits or compartments which must be entered.

b. have handrails on both sides, and treads of non-slip material.

Stairs are preferred in areas where there is frequent traffic or where supplies are transported by hand. They shall have risers not exceeding 9 inches and treads wide enough for safety.

7.3.4 Heating - Provision shall be made for adequate heating for:

a. comfort of the operator;

b. the safe and efficient operation of the equipment.

In pump houses not occupied by personnel, only enough heat need be provided to prevent freezing of equipment or treatment process.

7.3.5 Ventilation - Adequate ventilation shall be provided for all pumping stations. Forced ventilation of at least 6 changes of air per hour shall be provided for:

a. all rooms, compartments, pits and other enclosures below grade floor;

b. any area where unsafe atmosphere may develop or where excessive heat may be built up.

7.3.6 Dehumidification - In areas where excess moisture could cause hazards to safety or damage to equipment means for dehumidification shall be provided.

7.3.7 Lighting - Pump stations shall be adequately lighted throughout. All electrical work shall conform to the requirements of the American Insurance Association and related agencies and to relevant State and/or local codes.

7.3.8 Sanitary and Other Conveniences - Pumping stations which are manned for extended periods shall be provided with potable water, lavatory and toilet facilities. Plumbing must be so installed as to prevent contamination of a public water supply. Wastes shall be discharged in accordance with Section 4.11 of these standards.

7.3.9 Pumps - At least 2 pumping units shall be provided. Each pumping unit shall be capable of carrying the peak demand. If more than 2 units are installed, they shall have sufficient capacity so that any 1 pump can be taken out of service and the remaining pumps are capable of carrying the peak demand. The pumping units shall:

a. have ample capacity to supply the peak demand without dangerous overloading;

b. be driven by a prime mover able to operate against the maximum head and air temperature which may be encountered;

c. have spare parts and tools readily available.

3600 RPM pumps are not desirable and should be avoided if at all possible.

7.3.10 Suction Lift - Suction lift pumps will be considered on an individual basis based on justification of design engineer.

7.4 BOOSTER PUMPS - Booster pumps shall be located or controlled so that:

a. they will not produce negative pressure anywhere in the distribution system;

b. the pressure in the suction line shall be maintained at or above 20 psi by the use of a pressure sustaining valve or low pressure cutoff device.

c. automatic or remote control devices shall have a range between the start and cutoff pressure which will prevent excessive cycling.

7.4.1 In-line Booster Pumps - In addition to the other requirements of this section, in-line booster pumps shall be accessible for servicing and repairs.

7.4.2 The criteria in this section also apply to fire pumps.

7.4.3 Booster pumps shall not serve more than 50 service connections unless gravity storage is provided or service pressure can be maintained above 20 psi without the pumps running.

7.5 AUTOMATIC AND REMOTE CONTROLLED STATIONS - All automatic stations should be provided with automatic signaling apparatus which will report when the station is out of service. All remote controlled stations shall be electrically operated and controlled and shall have signaling apparatus of proven performance. Installation of electrical equipment shall conform with the National Electrical Code.

7.6 APPURTENANCES

7.6.1 Valves - Pumps shall be adequately valved to permit satisfactory operation, maintenance and repair of the equipment. If foot valves are necessary they shall have a net valve area of at least 2½ times the area of the suction pipe and they shall be screened. Each pump shall have a positive acting check valve on the discharge side between the pump and shutoff valve.

7.6.2 Piping - In general, piping shall:

a. be designed so that the friction head will be minimized;

b. not be subject to contamination;

c. have watertight joints;

d. be protected against surge or water hammer;

e. be such that each pump has an individual suction line or the lines shall be so manifolded that they will insure similar hydraulic and operation conditions.

7.6.3 Gauges and Meters - Each pump shall:

a. shall have a standard pressure gauge on its discharge line;

b. shall have a compound gauge on its suction line;

c. shall have recording gauges in larger stations;

d. should have a means for measuring the discharge.

The larger stations should have indicating, totalizing and recording metering of the total water pumped.

7.6.4 Water Seals - Water seals shall not be supplied with water of a lesser sanitary quality than that of the water being pumped.

7.6.5 Controls - Pumps, their prime movers and accessories, shall be controlled in such a manner that they will operate at rated capacity without dangerous overload. Where two or more pumps are installed, provision shall be made for proper alternation. Provision shall be made to prevent operation of the pump during the backspin cycle. Electrical controls should be located above grade.

7.6.6 Power - When power failure would result in cessation of minimum essential service, power supply shall be provided from at least two independent sources or standby or auxiliary source shall be provided.

7.6.7 Auxiliary Power Supply - When automatic pre-lubrication of pump bearings is necessary, and an auxiliary power supply is provided, the pre-lubrication line shall be provided with a valved by-pass around the automatic control.

Part 8 - FINISHED WATER STORAGE

8.0 GENERAL - The materials and designs used for finished water storage structures shall provide stability and durability as well as protect the quality of the stored water. Steel structures shall follow the current AWWA standards concerning steel tanks, standpipes, reservoirs, and elevated tanks wherever they are applicable. Prestressed concrete tanks shall meet applicable AWWA Standards. Other materials of construction are acceptable when properly designed to meet the requirements of this part.

8.0.1 Location

a. The bottom of ground-level reservoirs should be placed at the normal ground surface and above maximum flood level.

b. Where the bottom must be below normal ground surface, it should be placed above the ground water table. Sewers, drains, standing water, and similar sources of contamination must be kept at least 50 feet from the reservoir. Mechanical-joint water pipe, pressure tested in place to 50 psi without leakage, may be used for gravity sewers at lesser separations.

c. The top of a ground-level reservoir should not be less than 2 feet above normal ground surface and any possible flood level. Clearwells constructed under filters may be excepted from this requirement when the total design gives the same protection.

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.

8.0.3 Protection from Trespassers - Fencing, locks on access manholes, and other necessary precautions shall be provided to prevent trespassing, vandalism, and sabotage.

8.0.4 Drains - No drain on a water storage structure may have a direct connection to a sewer or storm drain. Splash pad and drainway shall be provided to prevent erosion.

8.0.5 Overflow - The overflow pipe of a water storage structure should be brought down near the ground surface and discharged over a drainage inlet structure or a splash plate and flow onto a drainway which is rip-rapped or otherwise protected to minimize erosion. No overflow may be connected directly to a sewer or storm drain.

a. When an internal overflow pipe is used, it shall be located in the access tube.

b. The overflow of a ground-level structure shall be high enough above normal or graded ground surface to prevent the entrance of surface water.

c. The overflow shall be protected with a twenty-four mesh non-corrodible screen and a flap valve.

8.0.6 Access - Finished water storage structures shall be designed with reasonably convenient access to the interior for cleaning and maintenance. Manholes on scuttles above waterline:

a. shall be framed at least 4 inches, and preferably 6 inches, above the surface of the roof at the opening; on ground-level structures manholes should be elevated 24 to 36 inches above the top or covering sod;

b. shall be fitted with a solid watertight cover which overlaps the framed opening and extends. down around the frame at least 2 inches;

c. should be hinged at one side;

d. shall have a locking device,

e. shall be a minimum of 20 inches in diameter or equivalent.

8.0.7 Vents - Finished water storage structures shall be vented by special vent structures. Open construction between the side wall and roof is not permissible. These vents:

a. shall prevent the entrance of surface water;

b. shall exclude birds and animals;

c. shall exclude insects and dust, as much as this function can be made compatible with effective venting; for elevated tanks and standpipes, 4-mesh non-corrodible screen may be used;

d. shall, on ground-level structures, terminate in an inverted U construction, the opening of which is 24 to 36 inches above the roof of sod and is covered with 24-mesh non-corrodible screen cloth.

8.0.8 Roof and Sidewall - The roof and sidewalls of all structures must be watertight with no openings except properly constructed vents, manholes, overflows, risers, drains, pump mountings, control ports, or piping for inflow and outflow.

a. Any pipes running through the roof or sidewall of a finished water storage structure must be welded or properly gasketed in metal tanks, or should be connected to standard wall castings which were poured in place during the forming of a concrete structure; these wall castings should have flanges embedded in the concrete.

b. openings in a storage structure roof or top, designed to accommodate control apparatus or pump columns, shall be curbed and sleeved with proper additional shielding to prevent the access of surface or slop water to the structure.

c. Valves and controls should be located outside the storage structure so that valve stems and similar projections will not pass through the roof or top of the reservoir.

8.0.9 Drainage for Roof or Cover - The roof or cover of the storage structure should be well drained, but downspout pipes shall not enter or pass through the reservoir; parapets, or similar construction which would tend to hold water and snow on the roof will not be approved.

8.0.10 Safety - The safety of employees must be considered in the design of the storage structure. As a minimum, such matters shall conform to pertinent laws and regulations.

a. Ladders, ladder guards, balcony railings, and safe location of entrance hatches shall be provided where applicable.

b. Elevated tanks with riser pipes over 8 inches in diameter shall have protective bars over the riser openings inside the tank.

8.0.11 Freezing - All finished water storage structures and their appurtenances, especially the riser pipes, overflows, and vents, shall be designed to prevent freezing which will interfere with proper functioning.

8.0.12 Grading - The area surrounding a ground-level structure should be graded in a manner that will prevent surface water from standing within 50 feet of the structure.

8.0.13 Silt stop - The discharge pipe of the reservoir shall be located in a manner that will prevent the flow of sediment into the distribution systems. Either a permanent or removable silt stop shall be provided at least 4 inches above the bottom of the storage structure.

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 current American Water Works Association standards, or otherwise acceptable to the Department shall be used. 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.

8.0.15 Turnover of water - If the storage reservoir is sized larger than required for initial demand and there is more than 2 days storage, provisions shall be made for turnover of the water in the tank and/or booster chlorination. Internal piping arrangements to prevent water stratification in ground level standpipes are recommended. For large, ground level tanks/reservoirs, piping and/or check valves can be installed to force water in and out of the tank at different locations in order to minimize dead/stagnant water zones.

8.0.16 Sampling - A suitable sampling tap should be provided on all storage structures and be protected from public access.

8.0.17 Disinfection - Finished water storage structures shall be disinfected in accordance with AWWA Standard C652 before being put in service.

8.1 PLANT STORAGE - The applicable design standards of this part shall be followed for plant storage.

8.1.1 Washwater Tanks - If washwater tanks are used, they shall be sized, in conjunction with available pump units and finished water storage, to give the back wash water required by Section 4.2.1.K.

a. Consideration must be given to the possibility of having to wash more than one filter at a time, or several filters in succession.

8.1.2 Clearwell - Clearwell storage should be sized, in conjunction with distribution system storage, to relieve the filters from having to follow fluctuations in water use to meet peak demands, including filter backwash water. Design shall include features to minimize short circuiting.

a. When finished water storage is used to provide proper contact time for chlorine, (see Section 4.4.2), special attention must be given to size and baffling.

b. An overflow shall be provided and must be protected with a screen and flap valve.

8.1.3 Adjacent Compartments - finished water must not be stored or conveyed in a compartment adjacent to unsafe water when the two compartments are separated by a single wall.

8.1.4 Basins and Wet-Wells - Receiving basins and pump wet-wells for finished water shall be designed as finished water storage structures.

8.2 PRESSURE TANKS - Hydropneumatic (pressure) tanks may be acceptable in some circumstances where the number being served is 50 connections or less. When used, they shall meet ASME code requirements or equal which comply with the requirements of state and local laws and regulations for the construction and installation of unfired pressure vessels.

8.2.1 Location - The tank should be located above normal ground surface and be completely housed, or earth-mounted with one end projecting into an operating house, to prevent freezing.

8.2.2 Bypass - tank should have bypass piping to permit operation of the system while the tank is being repaired or painted.

8.2.3 Appurtenances - Each tank should have an access manhole, a drain, a control equipment consisting of pressure gage, water sight glass, automatic or manual air blow-off, mechanical means for adding air, and pressure-operated start-stop controls for the pumps.

8.2.4 Sizing -

a. The capacity of each well and/or pump in a hydropneumatic system should be at least ten times the average daily consumption rate of the community or the maximum peak demand whichever is greater.

b. The gross volume of the hydropneumatic tank, in gallons, should be at least 20 times the capacity of the largest pump, rated in gallons per minute.

8.2.5 Auxiliary power - Auxiliary power with automatic takeover capability shall be provided when positive pressures are not available from system gravity flow.

8.3 DISTRIBUTION STORAGE - The applicable design standards of this part shall be followed for 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 flows when needed. For most water systems a satisfactory rule-of-thumb to meet these needs is to provide at least the average 24-hour demand in elevated storage. In the absence of an acceptable engineering study of the amount of water the system needs to meet customer demand and to provide for fire emergencies, the projected 24-hour demand at the end of the planning period will be the minimum requirement for elevated storage. This requirement may be reduced when the source, treatment facilities and pumps have sufficient capacity with standby power capability to supplement peak demands of the system.

8.3.2 Pressure Variation - System pressure variation on account of changes in level of water in storage structures should be minimized. Elevated storage tanks or large diameter ground tanks located on high ground should be the usual choices. Standpipes will not normally be approved and must be completely justified if proposed.

8.3.3 Drainage - Storage structures which float on the distribution system should be designed to drain for cleaning or maintenance without necessitating loss of pressure in the distribution system. The drains should discharge to the ground surface with no direct connection to a sewer or storm drain. (See Section 8.0.4). A nearby fire hydrant may be considered as a drain as long as service is not interrupted and suitable erosion protection is provided.

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 between the source and the storage structure.

b. Altitude valves or equivalent controls may be required for a second and subsequent structures on the system.

c. Overflow and low-level warnings or alarms should be located at places in the community where they will be under responsible surveillance on a 24-hour basis.

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.

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) 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. 0400-45-01-.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. 0400-45-01-.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

(a–f): 0400-45-01-.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

(g–k): 0400-45-01-.06 (6)(b) and (6)(c)

- **l) fecal coliform-positive repeat sample** violation
- **m) E. coli-positive repeat sample** violation
- **n)** violation

(l–n): 0400-45-01-.06

4) 1.0 **and** 2.0 - Page 16, 0400-45-01-.06(3)

5) a) 40 **and** 5 , 0400-45-01-.06(4)(a)(1); **b)** 40 **and** 1, 0400-45-01-.06(4)(a)(1)

Sampling

6) 30, 0400-45-01-.07(1)(c)

7) 9, 0400-45-01-.07(1)(c)

8) 24, 1, 1, 5, 5; 0400-45-01-.07(2)(a) and (b)

9) 4, 0400-45-01-.08(2)(a)

Operation and Maintenance Requirements

10) surface, filtration, iron, operator, operation; 0400-45-01-.17(1)

11) 10 days; 0400-45-01-.17(2)

12) "Standard Methods for the Examination of Water and Wastewater"; 0400-45-01-.17(3)

13) 0.2 mg/L; 0400-45-01-.17(4)

14) cross-connection, cross-connections; 0400-45-01-.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; 0400-45-01-.17(8)(a)

16) 20; 0400-45-01-.17(9)

17) flushing; **a)** date, **b)** time, **c)** location, **d)** persons responsible, **e)**length of flushing; 0400-45-01-.17(10)

18) duplicate; 0400-45-01-.17(11)

19) 4.0 gpm per square foot; 0400-45-01-.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; 0400-45-01-.17(12)(b) and (d)

21) 24, average daily, 12; 0400-45-01-.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; 0400-45-01-.17(15)

23) wells, storage, tanks, clearwells; 0400-45-01-.17(16)

24) 6, 500, 20; 0400-45-01-.17(18)

25) 0.9, 1.3; 0400-45-01-.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; 0400-45-01-.17(27)(a) and (b)

Section 12

Math Overview

Basic Math Concepts

3101 Introduction to Water Treatment

For Water and Wastewater Plant Operators
by Joanne Kirkpatrick Price

Updated 11-2020

Solving for the Unknown Value (X)

Solving for X

- Solve for X

$$(4)(1.5)(x) = 1100$$

- X must be by itself on one side of equal sign
  - 4 and 1.5 must be moved away from X

$$x = \frac{1100}{(4)(1.5)}$$

$$x = 183.3$$

  - How was this accomplished?

Movement of Terms

- To understand how we move the numbers, we will need to consider more closely the math concepts associated with moving the terms.
- An equation is a mathematical statement in which the terms or calculation on one side equals the terms or calculation on the other side.

Movement of Terms

- To preserve this equality, anything done to one side of the equation must be done to the other side as well.

$$(3)(x) = 14$$

- Since X is multiplied by 3, you can get rid of the 3 by using the opposite process: division.

Movement of Terms

- To preserve the equation, you must divide the other side of the equation as well.

$$\frac{(\cancel{3})(x)}{\cancel{3}} = \frac{14}{3}$$

$$x = \frac{14}{3} \qquad x = 4.67$$

- Since both sides of the equation are divided by the same number, the value of the equation remains unchanged.

Example 1

$$730 = \frac{x}{3847}$$

What you do to one side of the equation, must be done to the other side.

$$730 = \frac{x}{3847} \times \frac{3847}{1}$$

$$\frac{3847}{1} \times 730 = \frac{x}{\cancel{3847}} \times \frac{\cancel{3847}}{1}$$

$$3847 \times 730 = x$$

$$2{,}808{,}310 = x$$

Example 2

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

Simplify

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

What you do to one side of the equation, must be done to the other side.

$$0.5 = \frac{4128.3}{x} \times \frac{x}{1}$$

$$\frac{x}{1} \times 0.5 = \frac{4128.3}{\cancel{x}} \times \frac{\cancel{x}}{1}$$

$$(x)(0.5) = 4128.3$$

$$\frac{(x)(\cancel{0.5})}{\cancel{0.5}} = \frac{4128.3}{0.5}$$

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

$$x = 8256.6$$

Solving for X when squared

- Follow same procedure as solving for X
- Then take the square root

$$x^2 = 15{,}625$$

$$\sqrt{x^2} = \sqrt{15{,}625}$$

$$x = 125$$

Example 3

$$(0.785)(x^2) = 2826$$

$$\frac{(\cancel{0.785})(x^2)}{\cancel{0.785}} = \frac{2826}{0.785}$$

$$x^2 = \frac{2826}{0.785}$$

$$x^2 = 3600$$

$$\sqrt{x^2} = \sqrt{3600}$$

$$x = 60$$

Fractions and Percents

Converting Decimals and Fractions

- To convert a fraction to a decimal
  - Simply divide the numerator by the denominator

$$\frac{1}{2} = 1 \div 2 = 0.5$$

$$\frac{10}{13} = 10 \div 13 = 0.7692$$

Percents and Decimals

- To convert from a decimal to a percent
  - Simply move the decimal point two places to the right

$$0.46 \Longrightarrow 46.0\%$$

- To convert from a percent to a decimal
  - Simply move the decimal two points to the left

$$79.5\% \Longrightarrow 0.795$$

- Remember:

  You CANNOT have a percent in an equation!!

Writing Equations

- Key words
  - **Of** means "multiply"
  - **Is** means "equal to"
- Calculate 25% of 595,000

$$25\% \times 595{,}000$$

$$0.25 \times 595{,}000$$

$$148{,}750$$

Example 5

448 is what percent of 560?

$$448 = x\% \times 560$$

$$\frac{448}{560} = \frac{x\% \times 560}{560}$$

$$0.80 = x\%$$

$$80\% = x$$

Solving for the Unknown

<u>Basics – finding x</u>

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

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

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

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. 5.7
3. 5.3
4. 5,976,990
5. 8256.6
6. 8.1
7. 0.005
8. 360
9. 1649
10. 244.7
11. 11
12. 5
13. 7994
14. 590.4
15. 2817
16. 4903
17. 547,616
18. 117
19. 508,000
20. 0.35

Finding x^2

21. 80
22. 12
23. 40
24. 0.83
25. 10.9

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%

DIMENSIONAL ANALYSIS

Mathematics Manual for Water and Wastewater Treatment plant Operators
by Frank R. Spellman

Dimensional Analysis

- Used to check if a problem is set up correctly
- Work with the units of measure, not the numbers
- Step 1:
  - Express fraction in a vertical format

$$gal/ft^3 \text{ to } \frac{gal}{ft^3}$$

- Step 2:
  - Be able to divide a fraction

$$\frac{\frac{lb}{day}}{\frac{min}{day}} \text{ becomes } \frac{lb}{day} \times \frac{day}{min}$$

Dimensional Analysis

- Step 3:
  - Know how to divide terms in the numerator and denominator
  - Like terms can cancel each other out
    - For every term that is canceled in the numerator, a similar term must be canceled in the denominator

$$\frac{lb}{\cancel{day}} \times \frac{\cancel{day}}{min} = \square$$

- Units with exponents should be written in expanded form

$$ft^3 = (ft)(ft)(ft)$$

Example 1

- Convert 1800 ft³ into gallons.
- We need the conversion factor that connects the two units
- This is a ratio, so it can be written two different ways
- We want to use the version that allows us to cancel out units

$$\frac{1\,ft^3}{7.48\,gal} \text{ OR } \frac{7.48\,gal}{1\,ft^3}$$

Example 1

$$\left(\frac{1800\,ft^3}{1}\right)$$

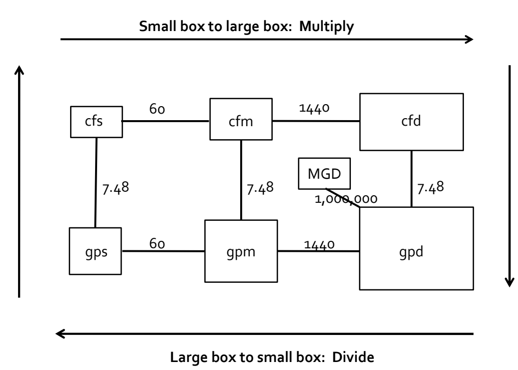
- Will anything cancel out?

NO

- Let's try the other version
- Will anything cancel out?

YES

Flow Conversions – Box Method



Metric System & Temperature

For Water and Wastewater Plant Operators

by Joanne Kirkpatrick Price

Metric Units

Primary Unit

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

↓

meter – linear measurement
liter – volume measurement
gram – weight measurement

King Henry Died By Drinking Chocolate Milk

Problem 1

- Convert 2500 milliliters to liters

Primary Unit

kilo	hecto	deka	no	deci	centi	milli
(k)	(h)	(da)	prefix	(d)	(c)	(m)

- Converting milliliters to liters requires a move of three place values to the left
- Therefore, move the decimal point 3 places to the left

2 5 0 0. = [ ]
3 2 1

Problem 2

- Convert 0.75 km into cm

Primary Unit

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

- From kilometers to centimeters there is a move of 5 value places to the right

0. 7 5 = [ ]
1 2 3 4 5

General Conversions

1. 325 ft^3 = gal

2. 2512 kg = lb

3. 2.5 miles = ft

4. 1500 hp = kW

5. 2.2 ac-ft = gal

6. 2100 ft^2 = ac

7. 92.6 ft^3 = lb

8. 17,260 ft^3 = MG

9. 0.6% = mg/L

10. 30 gal = ft^3

11. A screening pit must have a capacity of 400 ft^3. How many lbs is this?

12. A reservoir contains 50 ac-ft of water. How many gallons of water does it contain?

13. 3.6 cfs = gpm

14. 1820 gpm = gpd

15. 45 gps = cfs

16. 8.6 MGD= gpm

17. 2.92 MGD = lb/min

18. 385 cfm = gpd

19. 1,662 gpm = lb/day

20. 3.77 cfs = MGD

21. The flow through a pipeline is 8.4 cfs. What is the flow in gpd?

22. A treatment plant receives a flow of 6.31 MGD. What is the flow in cfm?

Basic Conversions Extra Problems

1. How many seconds are in a minute?

2. How many minutes are in an hour?

3. How many hours in a day?

4. How many minutes in a day?

5. How many inches in a foot?

6. How many feet in a mile?

7. How many feet in a meter?

8. How many meters in a mile?

9. How much does one gallon of water weigh?

10. How much does one cubic foot of water weigh?

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

12. What is 38 gps expressed as gpd?

13. What is 0.7 cfs expressed as gpd?

14. What is 9164 gpm expressed as cfs?

15. What is 1.2 cfs expressed as MGD?

16. Convert 65 gpm into lbs/day.

17. Convert 345 lbs/day into gpm.

18. Convert 0.9 MGD to cfm.

19. Convert 1.2 MGD to ft^3/hour.

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

21. What is 5.6 MGD expressed as cfs?

22. Express 423,690 cfd as gpm.

23. Convert 2730 gpm to gpd.

24. Convert 1440 gpm to MGD.

25. Convert 45 gps to ft^3/day.

Volume and Flow Conversions

1. 2,431 gal
2. 5,533 lb
3. 13,200 ft
4. 1,119 kW
5. 717,200 gal
6. 0.05 ac
7. 5,778.24 lb
8. 0.13 MG
9. 6,000 mg/L
10. 4.01 ft^3
11. 24,960 lb
12. 16,300,000 gal
13. 1,615.68 gal/min
14. 2,620,800 gal/day
15. 6.02 ft^3/sec
16. 5,968.4 gpm
17. 16,911.67 lb/min
18. 4,146,912 gal/day
19. 19,959,955.2 lb/day
20. 2.43 MGD
21. 5,428,684.8 gal/day
22. 585.82 ft^3/min

Basic Conversions Extra Problems

1. 60 sec
2. 60 min
3. 24 hr
4. 1440 min
5. 12 in
6. 5280 ft
7. 3.28 ft
8. 1610 m
9. 8.34 lbs
10. 62.4 lbs
11. 2244 gpm
12. 3,283,200 gpd
13. 452,390 gpd
14. 20.42 cfs
15. 0.78 MGD
16. 780,624 lbs/day
17. 0.03 gpm
18. 83.56 ft^3/min
19. 6684.49 ft^3/hr
20. 396.43 ft^3/min
21. 8.67 cfs
22. 2200.83 gpm
23. 3,931,200 gpd
24. 2.07 MGD
25. 519,786.10 ft^3/day

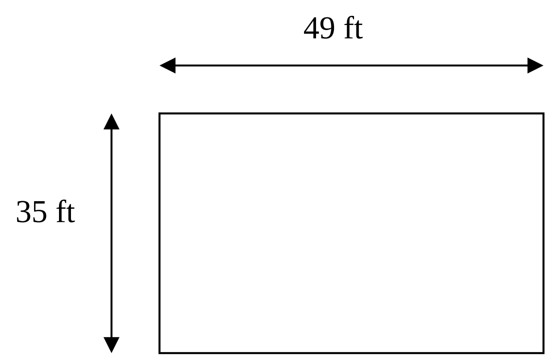
Math Problem Strategies

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.

Known		**Unknown**
Length = 35 ft Width = 49 ft	$A = (l)(w)$ $A = (35\text{ ft})(49\text{ ft})$ $A = 1715\text{ ft}^2$	Area = ?

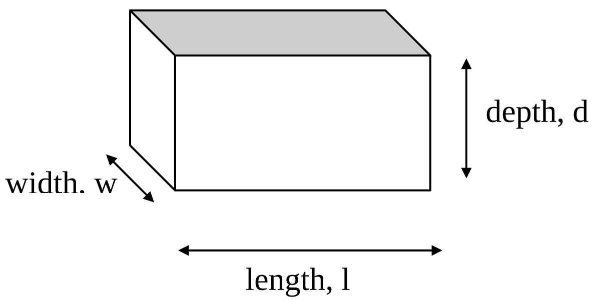


*****Remember: make sure measurements agree; if diameter of pipe is in inches then change to feet; if flow is in MGD and you need feet or feet/sec then change to ft^3/sec before you plug values into formula.***

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	$^{1}/_{10}$	$^{1}/_{100}$	$^{1}/_{1,000}$		$^{1}/_{1,000,000}$

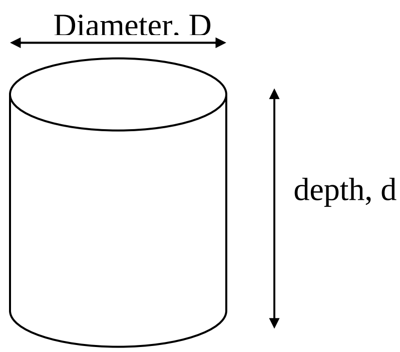
Tank Volume Calculations: Most tank volumes calculations are for tanks that are either rectangular or cylindrical in shape.

Rectangular Tank



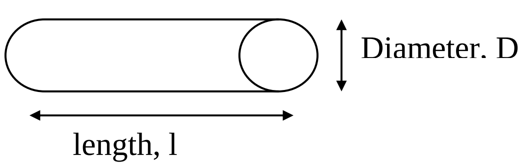
Volume = (l)(w)(d)

Cylindrical Tank



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

Portion of a Pipeline



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

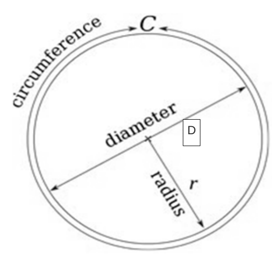
CIRCUMFERENCE AND AREA

Suggested Strategy to Solving Word Problems

- Disregarding all numbers, what type of problem is it?
- What diagram, if any, is associated with the concept identified?
- What information is required to solve the problem and how is it expressed in the problem?
- What is the final answer?
- Does the answer make sense?

Parts of a Circle

- Diameter is distance across the center of circle
- Radius is distance from circle's center to the edge
- Circumference is the distance around a circle or a circular object



Circumference & Perimeter

- Circumference of a Circle

$$Circumference = (3.14)(Diameter)$$

Example 1

- Find the circumference in inches of a 6 inch diameter pipe.

$$Circumference = (3.14)(diameter)$$

$$C = (3.14)(6\ inches)$$

$$C = 18.85\ inches$$

Area

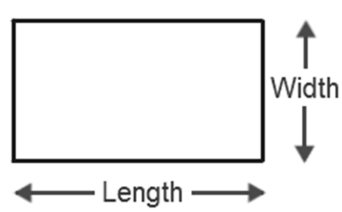
- Area is the measurement of the amount of space on the surface of an object
- Two dimensional measurement
- Measured in: in^2, ft^2, acres, etc.

Area

- Area of Rectangle

$$Area = (length)(width)$$

$$A = (L)(W)$$



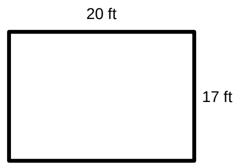
Example 2

- Find the area in ft² of a rectangular basin that is 20 feet long and 17 feet wide.

$$A = (L)(W)$$

$$A = (20ft)(17ft)$$

$$A = 340ft^2$$

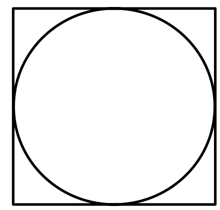


Area

- Area of Circle

$$Area = (0.785)\ (Diameter)^2$$

$$A = (0.785)(D)^2$$



A circle takes up 78.5% of a circle.

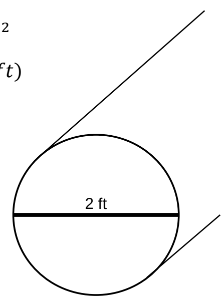
Example 3

- Find the area of the cross section of a pipe in ft² that has a diameter of 2 feet.

$$Area = (0.785)(D)^2$$

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

$$A = 3.14\ ft^2$$

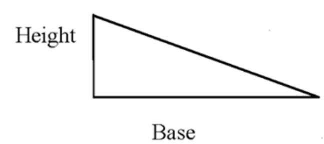


Area

- Area of Right Triangle

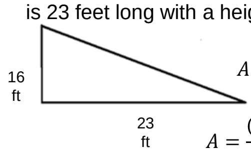
$$Area = \frac{(base)(height)}{2}$$

$$A = \frac{(b)(h)}{2}$$



Example 3

- Determine the area in ft² of a right triangle where the base is 23 feet long with a height of 16 feet.



$$A = \frac{(b)(h)}{2}$$

$$A = \frac{(23ft)(16ft)}{2}$$

$$A = \frac{368ft^2}{2}$$

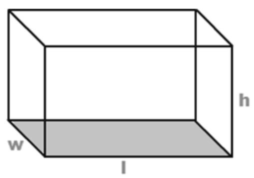
$$A = 184ft^2$$

Volume

Volume of a Rectangle

$$Volume = (length)(width)(height)$$

$$Vol = (l)(w)(h)$$



Example 1

- Determine the volume in m^3 for a tank that measures 30 meters by 15 meters by 25 meters.

$$Vol = (l)(w)(h)$$

$$Vol = (30m)(15m)(25m)$$

$$Vol = 11{,}250\ m^3$$

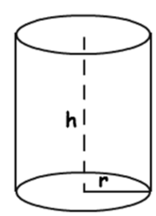
Volume

- Volume is the capacity of a unit or how much it will hold
- Measured in
  - cubic units (ft^3, m^3, yd^3) or
  - liquid volume units (gallons, liters, million gallons)
- The answer will come out in cubic units
  - You must then convert it to liquid volume units

Volume of a Cylinder

$$Volume = (0.785)(Diameter^2)(height)$$

$$Vol = (0.785)(D^2)(h)$$



Example 2

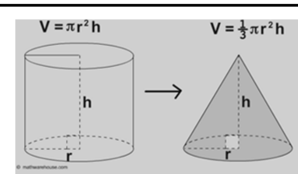
- Determine the volume in ft^3 for a tank that is 20 feet tall with a diameter of 7.5 ft.

$$Vol = (0.785)(D)^2(h)$$

$$Vol = (0.785)(7.5ft)(7.5ft)(20ft)$$

$$Vol = 883.13\ ft^3$$

Volume of a Cone



$$Volume = (1/3)(0.785)(Diameter^2)(height)$$

$$Vol = (1/3)(0.785)(D^2)(h)$$

Example 3

- Determine the volume in gallons of a conical tank that is 8 feet wide and 15 feet tall.

$$Vol = (1/3)(0.785)(D^2)(h)$$

$$Vol = (1/3)(0.785)(8ft)(8ft)(15ft)$$

$$Vol = (0.3333)(753.6\ ft^3)$$

$$Vol = 251.1749\ ft^3$$

$$Vol, gal = (251.1749\ \cancel{ft^3})(7.48\ \frac{gal}{\cancel{ft^3}})$$

$$Vol, gal = 1878.78\ gallons$$

Circumference, Area, and Volume Examples

1. Calculate the circumference in ft of a circular clarifier that is 30 feet in diameter.

2. A sedimentation tank is 20 feet long and 12 feet wide and 15 ft deep. What is the area (ft^2) of the water surface in the tank?

3. What is the cross-sectional area (ft^2) of an 18 inch water main?

4. A triangular portion of the treatment plant grounds is not being used. How many square feet does this represent if the height of the triangle is 140 ft and the base is 180 ft?

5. Calculate the lateral surface area, in ft^2, for a conical tank that 30 feet tall and 20 feet wide.

6. Determine the total surface area, in ft^2, of a conical tank that is 15 feet tall and 30 feet wide.

7. A new water tank needs to be painted. What is the total exterior surface area if the cylindrical tank is 50 feet in diameter and 30 feet tall, in ft^2?

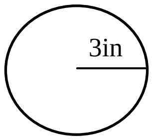
8. What is the volume in ft^3 of water contained in a round tank that is 20 feet across with water to a depth of 28 feet?

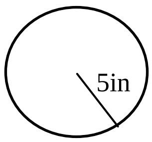
9. Calculate the holding capacity in gallons of a tank that is 15 feet wide, 15 feet long, and 20 feet tall.

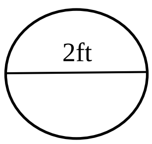
10. How many cubic feet of water is contained in a conical clarifier if the water is 8 feet deep and the distance across the clarifier at the water level is 21.7 feet?

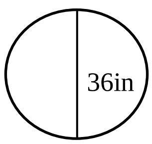
Basic Math for Water and Wastewater
CIRCUMFERENCE, AREA, AND VOLUME

Circumference

1. 

2. 

3. 

4. 

5. A chemical holding tank has a diameter of 24 feet. What is the circumference of the tank in feet?

6. An influent pipe inlet opening has a diameter of 4 feet. What is the circumference of the inlet opening in inches?

7. What is the length (in feet) around the top of a circular clarifier that has a diameter of 32 feet?

Area

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

2. If the diameter of a circle is 10 inches, what is the cross-sectional area in square feet?

3. Calculate the surface area (in ft^2) of the top of basin which is 90 feet long, 25 feet wide, and 10 feet deep.

4. Calculate the area (in ft^2) for a 2 ft diameter main that has just been laid.

5. What is the area of the rectangle that is 3 feet by 9 feet?

6. Calculate the area (in ft^2) for an 18” main that has just been laid.

Volume

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

2. Calculate the volume (in gallons) for a basin that measures 22 feet by 11 feet by 5 feet.

3. Calculate the volume of water in a tank (in gallons), which measures 12 feet long, 6 feet wide, 5 feet deep, and contains 8 inches of water.

4. Calculate the volume (in ft^3) of a cone shaped chemical hopper with a diameter of 12 feet and a depth of 18 feet.

5. A new water main 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?

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

DON'T THINK TOO HARD ON THIS ONE...

7. If you double the size of a pipe, does it double the volume that can be carried? For example, if you have 1000 feet of 12 inch line and you replace it with a 24 inch line, does your volume double?

ANSWERS:

Circumference	Area	Volume
1. 18.85 in	1. 540 ft^2	1. 1000 ft^3
2. 31.42 in	2. 0.55 ft^2	2. 9050.8 gal
3. 6.28 ft	3. 2250 ft^2	3. 359.04 gal
4. 113.10 in	4. 3.14 ft^2	4. 678.58 ft^3
5. 75.40 ft	5. 27 ft^2	5. 48442.35 gal
6. 150.80 in	6. 1.77 ft^2	6. 150,000 gal
7. 100.53 ft		7. No, it quadruples it (4X)

Velocity & Flow

Velocity

- The speed at which something is moving
- Measured in
  - $^{ft}/_{min}$ $^{ft}/_{sec}$ $^{miles}/_{hr}$ etc

$$Velocity = \frac{distance}{time}$$

Example 1

- Blue dye is placed in a sewer line at a manhole. Three (3) minutes later, the dye appears in a manhole 125 feet down stream. What is the velocity of the flow in ft/min?

$$Velocity = \frac{distance}{time}$$

$$Vel = \frac{125\ ft}{3\ min}$$

$$Vel = 41.67\ ^{ft}/_{min}$$

Flow

- The volume of water that flows over a period of time
- Measured in
  - $^{ft^3}/_{sec}$ $^{ft^3}/_{min}$ $^{gal}/_{day}$ $^{MG}/_{D}$

$$Flow = (Area)(Velocity)$$

$$Q = AV$$

Example 2

- Water is flowing at velocity 3 ft/sec through a channel that is 2 feet wide and 1.5 feet deep. What is the flow in cubic feet per second?

$$Q = AV$$

$$Q = (l)(w)(velocity)$$

$$Q = (2ft)(1.5ft)\left(3\ ^{ft}/_{sec}\right)$$

$$Q = 9\ ^{ft^3}/_{sec}$$

Example 3

- Determine the flow in ft^3/sec through a 6 inch pipe that is flowing full at a velocity of 4.5 ft/sec.

$$D = (6\ in)\left(\frac{1\ ft}{12\ in}\right) \qquad Q = AV$$

$$D = 0.5\ ft \qquad Q = (0.785)(D^2)\ (vel)$$

$$Q = (0.785)(0.5\ ft)(0.5\ ft)\left(4.5\ ^{ft}/_{sec}\right)$$

$$Q = 0.88\ ^{ft^3}/_{sec}$$

Velocity and Flow Examples

1. A bobber is placed in a channel and travels 450 feet in 2 ½ minutes. What is the velocity of the water flowing in the channel in ft/min?

2. A channel 30 inches wide has water flowing to a depth of 2 feet. If the velocity of the water is 2.75 ft/sec, what is the flow in the channel in ft^3/sec? And gal/min?

3. The flow through a 24 inch pipe is moving at a velocity of 5.4 ft/sec. What is the flow rate in gal/min?

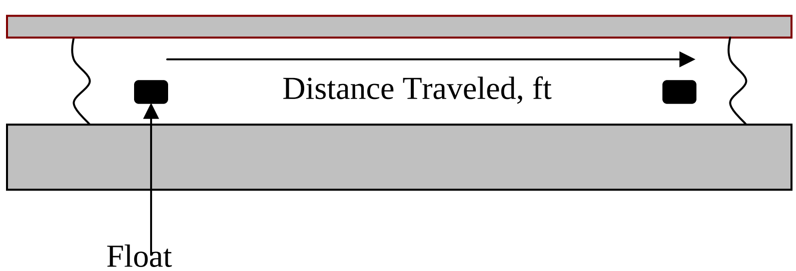
Basic Math for Water and Wastewater
Flow and Velocity

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?

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

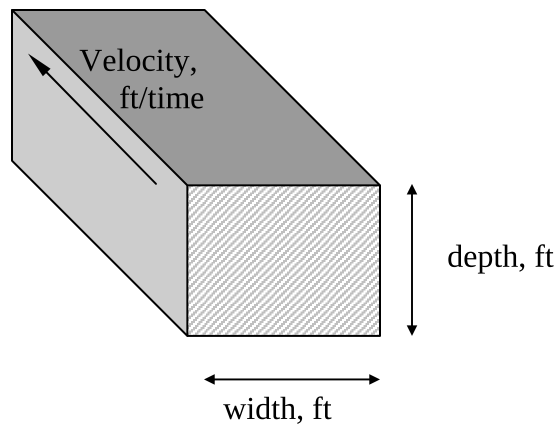
3. The distance between manhole #1 and manhole #2 is 105 feet. A fishing bobber is dropped into manhole #1 and enters manhole #2 in 30 seconds. What is the velocity of the wastewater in the sewer in ft/min?



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

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

1.) 185 ft/min 2.) 2.2 ft/sec 3.) 210 ft/min



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

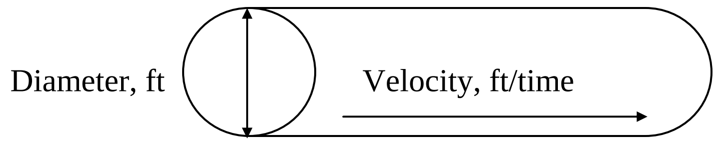
<u>Flow in a channel</u>

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?

4.) 16.8 ft^3/sec 5.) 900 ft^3/min; 9.7 MGD 6.) 1.8 ft



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

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

<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?

7.) 10.05 ft3/sec 8.) 0.59 ft3/sec 9.) 6 in 10.) 532.4 gpm

Basic Math for Water and Wastewater
FLOW RATE

Q = AV

1. A channel is 3 feet wide with water flowing to a depth of 2 feet. If the velocity in the channel is found to be 1.8 fps, what is the cubic feet per second flow rate in the channel?

2. A 12-inch diameter pipe is flowing full. What is the cubic feet per minute flow rate in the pipe if the velocity is 110 feet/min?

3. A water main with a diameter of 18 inches is determined to have a velocity of 182 feet per minute. What is the flow rate in gpm?

4. A 24-inch main has a velocity of 212 feet/min. What is the gpd flow rate for the pipe?

5. What would be the gpd flow rate for a 6” line flowing at 2 feet/second?

6. A 36” water main has just been installed. According to the Design Criteria for the State of Tennessee, the minimum flushing velocity is 2 ft/sec. If the main is flushed at 2.5 ft/second, how many gallons/minute should be flushed from the hydrant?

7. A 36” water main has just been installed. If the main is flows at 2 ft/second, how many MGD will the pipe deliver?

8. A certain pipe has a diameter of 18 inches. If the pipe is flowing full, and the water is known to flow a distance of 830 yards in 5 minutes, what is the MGD flow rate for the pipe?

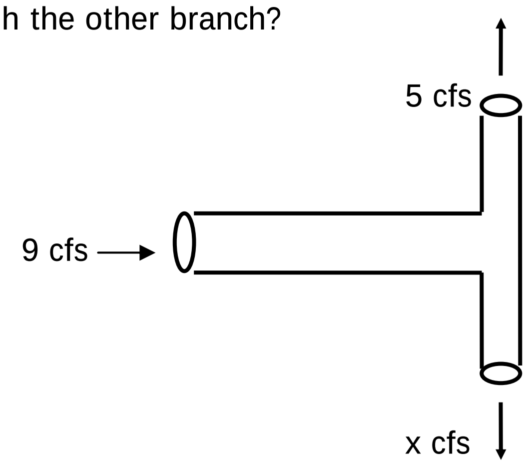
9. A float is placed in a channel. It takes 2.5 minutes to travel 300 feet. What is the velocity in feet per minute in the channel? (Assume that float is traveling at the average velocity of the water.)

10. A cork placed in a channel travels 30 feet in 20 seconds. What is the velocity of the cork in feet per second?

11. A channel is 4 feet wide with water flowing to a depth of 2.3 feet. If a float placed in the channel takes 3 minutes to travel a distance of 500 feet, what is the cubic-feet-per-minute flow rate in the channel?

12. The average velocity in a full-flowing pipe is measured and known to be 2.9 fps. The pipe is a 24” main. Assuming that the pipe flows 18 hours per day and that the month in question contains 31 days, what is the total flow for the pipe in MG for that month?

13. The flow entering the leg of a tee connection is 9 cfs. If the flow through one branch of the tee is 5 cfs, what is the flow through the other branch?



ANSWERS:

1. 10.8 ft^3/sec
2. 86.35 ft^3/min
3. 2,404.50 gpm
4. 7,170,172.42 gpd
5. 253,661.76 gpd
6. 7,926.93 gpm
7. 9.13 MGD
8. 9.47 MGD
9. 120 ft/min
10. 1.5 ft/sec
11. 1,533.33 ft^3/min
12. 136.83 MG
13. 4 ft^3/sec