Small Water Systems

Course # 2001

TN Department of Environment & Conservation

Fleming Training Center
Your Partner in Clean Water

State of Tennessee
Dept. of Environment & Conservation
Bureau of Environment
Fleming Training Center

#2001 Small Water Systems

February 6-8, 2018

Instructor: Amanda Carter
Fleming Training Center

Tuesday, February 6

8:30	Welcome and Roll Call
8:45	Water Sources and Treatment
9:15	Wells
9:45	Small Water Plants
11:00	Lunch
12:15	Disinfection
1:45	Safety

Wednesday, February 7

8:30	Pumps & Equipment Maintenance	
10:00	Cross Connection Control	
11:00	Lunch	
12:15	Rules and Regulations Wellhead Protection	Scotty Sorrells Div. Water Resources scotty.sorrells@tn.gov
2:00	Laboratory	

Thursday, February 8

8:30	Basic Math
11:00	Lunch
12:15	Applied Math
2:30	Exam and Course Evaluation

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Table of Contents

Section 1

Water Sources

Water Sources and Treatment

Small Water System Operation and Maintenance
California State University: Sacramento

Water Supply Hydrology and the Hydrologic Cycle

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

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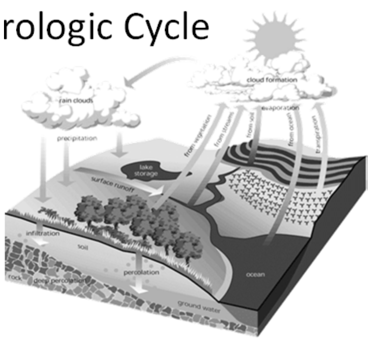
Hydrologic Cycle



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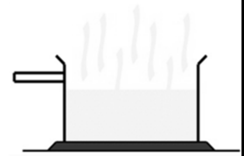
Hydrologic Cycle

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



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Hydrologic Cycle

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

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Hydrologic Cycle

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

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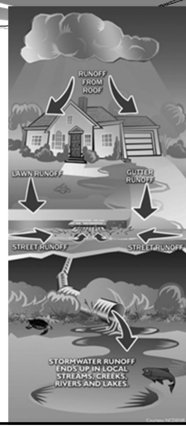
Hydrologic Cycle

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



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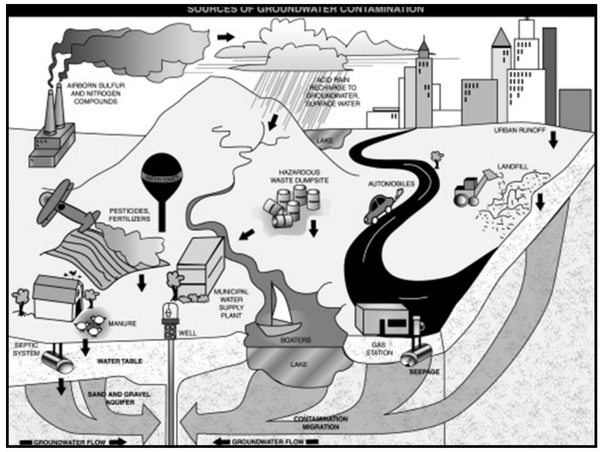

Groundwater

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

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Groundwater

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

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Aquifers

Unconfined Aquifers

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

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Aquifers

Confined Aquifers

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

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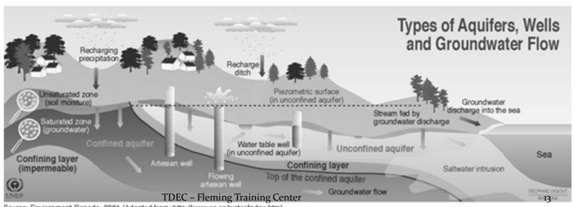
Aquifers

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



Source: Environment Canada, 2001 (Adapted from: http://www.ec.ca/water/index.htm)

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Aquifers Terms & Materials

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

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Groundwater Movement Characteristics

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

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Springs

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

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Surface Water Characteristics

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

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Surface Water Supply and Operating Problems

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

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Vocabulary

A. Aesthetic
B. Appropriative Rights
C. Aquifer
D. Artesian
E. Capillary Fringe
F. Contamination
G. Cross Connection
H. Direct Runoff
I. Drawdown
J. Evaporation
K. Evapotranspiration
L. Hydrologic Cycle
M. Infiltration

1. _____ The process by which water or other liquid becomes a gas.
2. _____ The porous material just above the water table that may hold water by capillarity in the smaller void spaces
3. _____ The seepage of groundwater into a sewer system, including service connections
4. _____ Attractive or appealing
5. _____ A natural, underground layer of porous, water-bearing materials (sand, gravel) usually capable of yielding a large amount or supply of water
6. _____ The process by which water vapor is released to the atmosphere from living plants
7. _____ The introduction into water of microorganisms, chemicals, toxic substances, wastes, or wastewater in a concentration that makes the water unfit for its next intended use
8. _____ The process of evaporation of water into the air and its return to earth by precipitation.
9. _____ Water rights to or ownership of a water supply that is acquired for the beneficial use of water by following a specific legal procedure
10. _____ A connection between a potable water and an unapproved water supply.

11._____ Pertaining to groundwater, a well, or underground basin where the water is under a pressure greater that atmospheric and will rise above the level of its upper confining surface if given an opportunity to do so
12. _____ Water that flows over the ground surface directly into streams, rivers, or lakes
13. _____ The drop in the water table or level of water in the ground when water is being pumped from a well

Answers

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

Section 2

Wells

Wells

1

SMALL WATER SYSTEM OPERATION AND MAINTENANCE
CALIFORNIA STATE UNIVERSITY: SACRAMENTO

Groundwater

2

Importance of Groundwater

3

- Function of well is intercept ground water moving through aquifers and bring water to surface
- Reasons for choosing groundwater source:
  - Generally available in all regions, though quantities may be limited
  - Less costly than surface treatment facilities
  - Less bacterial and viral contamination
  - Water quality parameters generally constant
  - Well suited to the needs of smaller communities

Water Cycle

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- Hydrologic cycle is the continuous circulation of water on our planet
- Subsurface water - water that infiltrates the soil
  - Not all will become groundwater
- Capillary action may pull water back to the surface
  - Will then be evaporated
- Water may be absorbed by plant roots
  - Reenters atmosphere through transpiration
- Infiltrated water may be drawn down to the zone of saturation – groundwater reservoir that supplies water to wells

Aquifers

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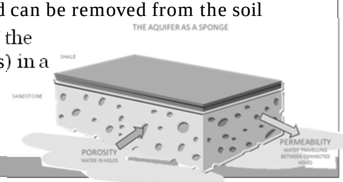
- To qualify as an aquifer:
  - Porosity, area, & thickness to store adequate water supply
  - Sufficient specific yield to allow water to drain to a well
  - Hydraulic transmissivity to permit well to drain water from the aquifer fast enough to meet flow requirements
- Specific yield – the volume of water that is affected by gravitational forces and can be removed from the soil
- Porosity - a measure of the opening or voids (pores) in a particular soil



Overdraft

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- Overdraft – pumping of water from aquifer in excess of the safe yield
- Overdraft can lead to the drained soils settling resulting in compaction and closing of pores
  - Subsidence of the land

Wellhead Protection

7

- Contamination can originate on the ground surface, in the ground above the well, or in the ground below the water table
  - Best method to guarantee continued supplies of clean groundwater is to prevent contamination
- Potential problems
  - Agriculture – pesticides, manure, nitrates
  - Gas stations – minor leaks, incidental spills
  - Fuel storage – underground tank failure, above ground tanks, buried & abandoned tanks
  - Photo labs, Dry cleaners, Furniture strippers, Medical Labs – solvents are very persistant
  - Septic systems -

Surface Features of a Well

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Well Surface Features

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- Openings in the top of the well allow for entrance or escape of air or gas
  - Provides access for adding gravel, taking water level readings, adding disinfectant or cleaning chemicals
- Openings are second most important part of well
- Well casing vent
  - Prevents vacuum forming during initial drawdown by allowing air to enter well
    - Drawdown – drop in water level in the ground when water is being pumped from a well
  - Prevents pressure buildup during recovery period by allowing air to escape
  - 3 inch diameter minimum
  - Wells over 14 inches should have a dual vent
  - Should be 36 inches above finished surface of well lot

Well Surface Features

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- Gravel tube
  - Required to monitor the gravel level and add level as needed
  - Typically 4 inches in diameter and tightly sealed
- Sounding tube
  - Used to determine water level and add disinfectant & cleaning agents
  - Minimum of 2 inches in diameter and tightly sealed
  - Well casing vent can be used as sounding tube
  - Disinfected roper or measuring tape is inserted into tube to the water level and the distance recorded
  - Can also use air pressure gauge – sounding line

Well Surface Features

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- Pump pedestal
  - Concrete designed to support the full weight of the pumping unit
  - Constructed of continuously poured concrete to a minimum height of 18 inches above the finished elevation of the well lot
    - Never less than 12 inches
  - Minimum three inches of concrete around the outside of conductor casing grout seal
  - Should enclose top of grout seal a minimum of 12 inches deep
  - Steel reinforcement of the pedestal is recommended
- Pump motor base seal
  - Watertight seal between pump motor base and concrete pedestal
  - Latex rubber, neoprene rubber, or regular rubber gasket material
    - Cement grout should be avoided as seal

Well Surface Features

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- Air release and vacuum breaker valve
  - If pump not equipped with foot valve, install this valve in the piping between the pump head and well discharge check valve
    - When pump is started, air will be expelled to the atmosphere instead of into the system
    - When pump is shutdown, air is admitted into the pump column allowing it to dewater into the well
    - Mount valve as close to check valve on top of discharge piping
    - Opening in top of valve must be equipped with downturned, screened assembly and protected from flooding

Well Surface Features

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- Sampling taps
  - Pet cock valve fitted with a 3/8 (three eighths) inch copper line with the outlet turned down
  - No hose bib, faucet or threaded valve should be installed between pump and check valve to minimize contamination
- Pump blowoff
  - Use to remove pumped water containing sand picked up at beginning of pumping cycle
  - Waste line must be located above any known flood levels and protected against backpressure or backsiphonage
  - Do not connect directly to any sewer or storm drain

Well Surface Features

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- Well-casing vent (1)
  - Allows air to enter well during drawdown to prevent vacuum conditions; vents excess air during well recovery period
- Gravel Tube (2)
  - Permits operator to see level of gravel and add gravel as needed
- Sounding tube (3)
  - Permits insertion of water level measuring device
  - Allows addition of chlorine or well cleaning agents

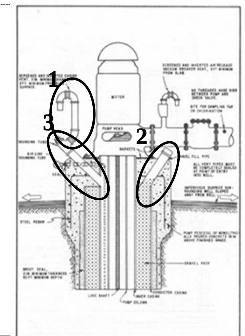

Figure 7. SURFACE CONSTRUCTION FEATURES COMMUNITY WATER SUPPLY WELL

Well Surface Features

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- Air line water level measuring device (1)
  - Aka Sounding line
  - Permits measurement of water level by means of air pressure measurements
- Pump pedestal(2)
  - Supports the weight of the pumping unit (concrete)
- Pump motor base seal (3)
  - Provides watertight seal between the motor base and the concrete support pedestal

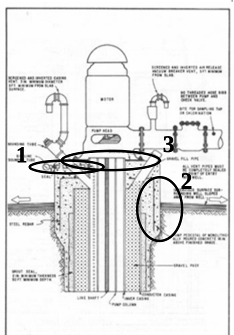

Figure 7. SURFACE CONSTRUCTION FEATURES COMMUNITY WATER SUPPLY WELL

Well Surface Features

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- Sampling taps (1)
  - Permit sampling of pumped water
- Air release and vacuum breaker valve (2)
  - Permits discharge of air in column pipe during start-up and admits air during shutdown
- Pump blowoff (drain line) (not shown)
  - Removes first water (usually sandy) pumped at start up

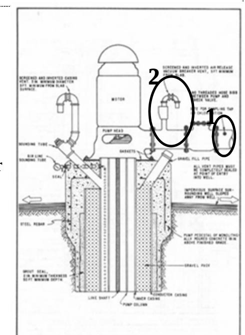

Figure 7. SURFACE CONSTRUCTION FEATURES COMMUNITY WATER SUPPLY WELL

Well Appurtenances

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Valves

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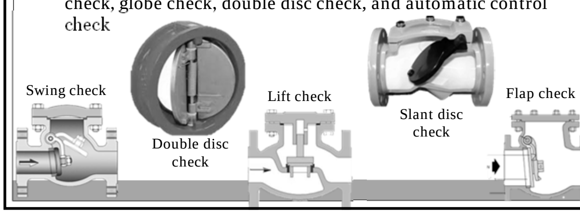
- Check valves
  - Prevents draining of system and keeps pressurized water from flowing back into the well
    - Flow reversal will not occur in pumps with a foot valve
  - Types: swing check, lift check, foot check, slant disc check, flap check, globe check, double disc check, and automatic control check



Valves

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- Pump control valves
  - diaphragm-type valve designed to eliminate pipeline surges when the pump is started and stopped (water hammer)
  - Types: normally open, normally closed
    - Both types hydraulically operated
  - Normally closed installed on main discharge line
  - Normally open installed in bypass line on discharge side
- Foot valves
  - Placed in the inlet to pump suction line
  - Maintains the prime of the pump
  - Prevents reversal of flow into the well when pump shuts off
  - Eliminates problems of air entering system

Flowmeters

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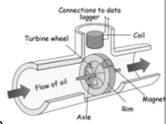
- Used to measure the amount of water being pumped to the system
  - Should be at least 5 pipe diameters distance downstream from any pipe bend, elbow or valve
  - Should be at least 2 pipe diameters distance upstream from any pipe bend, elbow or valve
  - Should be calibrated in place
  - Types:
    - Positive displacement, propeller, turbine, orifice plate, electronic sensor
      - Propeller or turbine type with magnetic drive most common in well pump applications



Sand Traps and Sand Separators

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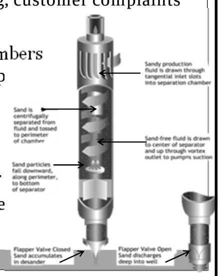
- Sand should not be allowed to enter the distribution system
  - Reduced pump efficiencies, worn impellers, sanded water mains, excessive meter wear & plugging, customer complaints
- Sand traps
  - Large tank with series of baffles or chambers installed on discharge side of well pump
  - Costly and inefficient
- Sand separators
  - Uses centrifugal force to efficiently remove fine sand, scale, etc. from water
  - Can remove approximately 95% of large sand particles



More Appurtenances

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- Tank coatings
  - 0400-45-01-.17(34) 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
- Surge suppressors
  - Installed on discharge side of booster pump to absorb shock waves in the water system and prevent water hammer
- Air and vacuum valves
  - Large venting orifice used to exhaust large quantities of air very rapidly
- Pressure relief valve
  - Installed on all hydropneumatic tanks to prevent water hammer

Air Chargers

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- Add air to hydropneumatic system
- Hydraulic principle air charger
  - Uses water pressure of tank to force air into tank
  - Air is added to tank on upward compression stroke and releases water on downward exhaust stroke
- Air compressor air charger
  - When water level switch exceeds preset level, air gets pumped into the tank to push out water
  - Pump runs until pressure rises enough to open pressure switch OR the water level descend below preset level

Well Maintenance and Rehabilitation

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Factors Affecting Maintenance of Well Performance

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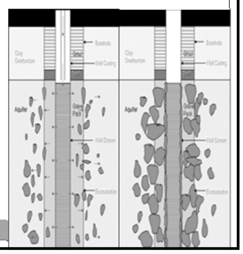
- Overpumping (aka overdraft)
  - Can damage aquifer and production capacity
  - Can lead to pumping air, water cascading into the well, sand pumping, excessive pump wear, reduced pump efficiency, sand locking
- Clogging or encrustation of screen
  - Well screens will filter sand out of water entering the well
  - Clogging/encrustation can limit number of available openings for water to move through
    - Encrusting waters usually alkaline
  - Most common cause of decrease in a well's capacity
  - Carbonate, sulfate, and iron deposits most common causes of encrustation



Factors Affecting Maintenance of Well Performance

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- Corrosion or collapse of screen
  - Corrosion is a process that results in the gradual decomposition or destruction of metals
  - Typical corrosive water characteristics
    - Acidic (low pH)
    - High dissolved oxygen (DO)
    - High carbon dioxide (CO_2)
    - High total dissolved solids (TDS)
    - High hydrogen sulfide (H_2S)
    - High velocity water
    - Connection of dissimilar metals in water (galvanic corrosion)
  - Can enlarge screen openings allowing unwanted, larger particles through

Factors Affecting Maintenance of Well Performance

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- Biofouling
  - Bacterial growth is responsible for more than 80% of the blockages in wells and a major portion of corrosion
  - Biofilm is habitat of bacteria
  - Results in blockage, corrosion, or water quality problems
- Field testing of deposits
  - Black deposit: iron sulfide or manganese
  - Dark to reddish brown: ferric iron oxide (soluble/dissolved)
  - Bright yellow: sulfur
  - Light tan deposit: mixture of calcium and magnesium carbonate
  - Very light color to white: calcium carbonate
  - Very heavy or dense deposit: predominately mineral
  - Very light or low density deposit: biological or organic material

Well Maintenance

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- Adequate recordkeeping is a must
  - Water level measurements before and after pumping
  - Flow rates
  - Water quality samples
  - Time length of pumping
  - Pump repairs
- Casing and screen maintenance
  - Material selection vital to life of well

Casing and Screen Maintenance

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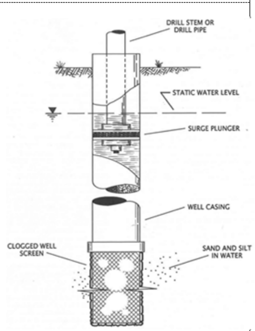
- Surging
  - Procedure used for opening pores in the screen and cleaning gravel pack
  - Common in new well development to purge sand around well screen
  - Effective at combating encrustation when used with acid treatment



Casing and Screen Maintenance

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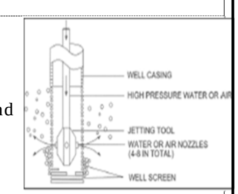
- High velocity jetting
  - Spraying water at a high velocity to backwash screen and reopen pores of the aquifer and remove sand around well screen
    - Jet should be 1-2 inches smaller than well casing diameter
    - 100-150 psi at 10-12 gpm
- Chlorine treatment
  - Shock treatment @ 100-200 mg/L
  - More effective than acid treatment removing biofilms and iron oxide deposits
  - Calcium hypochlorite or sodium hypochlorite
  - May be alternated with acid treatment



Casing and Screen Maintenance

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- Polyphosphates
  - Disperse silts, clays, and deposits of iron & manganese
  - Dislodged solids easily removed by pumping
- Acid treatment
  - Used to loosen encrustation to remove from well and casing
  - Hydrochloric acid or sulfamic acid
    - Dissolves calcium and magnesium carbonates
    - HCl – dissolves iron and magnesium hydroxides
  - Use caution to not damage well materials
  - Always add acid to water, never add water to acid
  - Pump well to waste until well discharge pH has returned to normal

Acid Treatment

Characteristic	Slight	Moderate	High
Corrosiveness to metal	Phosphoric acid Hydroxyacetic acid Citric acid	Sulfamic acid	Hydrochloric acid
Characteristic	**Poor**	**Good**	**Very Good**
Reactivity to:			
• Carbonate Scale	• Citric acid	• Hydroxyacetic acid	• Sulfamic acid, Hydrochloric acid, Phosphoric acid
• Sulfate Scale	• Hydroxyacetic acid, Citric acid	• Sulfamic acid, Hydrochloric acid, Phosphoric acid	
• Fe/Mn Oxides		• Sulfamic acid, Hydroxyacetic acid, Phosphoric acid, Hydrochloric acid	
• Biofilm	• Sulfamic acid, Hydrochloric acid, Phosphoric acid, Citric acid	• Hydroxyacetic acid	

Troubleshooting

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- Decline in yield
  - Yield depends on three factors: aquifer, well, pump
    - Decline in yield will be due to a change in one of these factors
  - Specific capacity – measure of the adequacy of an aquifer or well
    - Measures the yield of a well in gallons per minute per unit of drawdown during a specific time period (gpm/ft)
- Changes in water quality
  - Biological, chemical, or physical quality
  - Can be attributed to changes in the aquifer or well
    - Changes in aquifer – biological or chemical quality deterioration
    - Changes in well – physical quality deterioration

Troubleshooting

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Analysis of Declines in Well Yields

Symptom	Cause	Corrective Action
Decline in drawdown with no change in specific capacity	Aquifer – groundwater level decline due to reduced recharge or overpumping	Increase spacing of new supply wells. Institute artificial recharge methods.
Decline in specific capacity with no change in drawdown	Well – screen blockage; reduction in open hole by sediment	Clean well with surge block or other means. Acid wash to dissolve encrustations.
No change in drawdown and no change in specific capacity	Pump – wear of impeller or other moving parts	Recondition/replace motor or parts

Troubleshooting

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Analysis of Changes in Water Quality

Quality Change	Cause	Corrective Action
Biological	Movement of polluted water from surface through pipe liner and inside of pipe	Seal space and mound dirt around well
Chemical	Movement of polluted water into well from land surface	Seal space; extend casing to a deeper level
Physical	Migration of rock particles into well through screen or from water bearing fractures; Collapse of well screen or rupture of well casing	Remove pump and redevelop well Replace screen; install smaller casing inside original casing

Well Pumps and Service Guidelines

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Well Pumps

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- Two basic groups
  - Positive displacement pumps – deliver same volume of water against any head
    - Piston or diaphragm
  - Dynamic pumps – deliver water with the volume varying inversely with the head
    - The greater the head the less the volume or flow
    - Centrifugal, jet, and air-lift
- Shallow well pump – installed above a well and takes water by suction lift
- Deep well pump –installed in well with inlet submerged below pumping level
  - Can be used in any type of well

Types of Pumps

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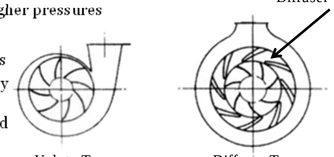
- Centrifugal pumps
  - Raises water by centrifugal created by impeller in a casing; water passes through a channel or diffuser vanes
  - Volute-type pumps
    - No diffuser
    - Lower velocity with higher pressures
  - Turbine-type pumps
    - Most common for wells
    - Impeller surrounded by diffuser vanes that transform velocity head to pressure head



Volute Type Diffuser Type

Types of Pumps

39

- Deep Well Turbine Pumps
  - Standard
    - Driven through rotating lineshaft connected to electric motor on top of well
      - Oil lubricated or water lubricated
  - Submersible
    - Similar to standard deep well turbine except motor is mounted below pump
- Jet pumps
- Piston pumps
- Rotary pumps

Well Pumps

40

- Column pipe
  - Connects to bottom of surface discharge head, extends down into well, and connects to the top of the well pump
  - Delivers water under pressure from well pump to surface
  - Keeps lineshaft and shaft enclosing tube assembly in straight line
- Right-angle gear drives
  - Can replace electric motor on top of well
  - Can be used with electric motor as a standby or for emergency purposes

Well Pumps

41

- Selecting a pump
  - Must know required capacity, location & operating conditions, and total head
- Service guidelines
  - Deep well turbine, oil lubricated pumps have electric oiler system that includes an adjusting needle and sight glass
    - Oil drip rate depends on well column length
    - Should never be less that 5 drops of oil per minute
- Motors
  - Oil in bearing container changed annually
    - Be sure to use proper oil
  - Greased bearings require weekly attention during heavy pumping season
    - Do NOT over grease bearings, will cause overheating

Disinfection of Wells and Pumps

42

New Wells

43

- For well disinfection procedures, follow AWWA A100
  - AWWA A100 says to follow AWWA C654
- Equipment and material should be sprayed with 200 mg/L chlorine just prior to installation
- After installation of equipment
  - Treat water in well casing to provide residual of 50 mg/L
  - Circulate chlorinated water within casing and well column
  - Pump well to waste to remove chlorinated water

Disinfection After Equipment Installation

44

- Treating water in well casing
  - Must have 50 mg/L chlorine residual in entire volume of water
  - Calcium hypochlorite (HTH)
    - Dribble down the casing vent and at least 30 minutes shall pass to allow the tablets to fall through the water and dissolve
  - Sodium hypochlorite
    - Suspend tube through well casing vent to bottom of well
    - Withdraw tube as sodium hypochlorite solution pumped through tube
  - Well shall be surged at least 3 times
    - Improves mixing and induces contact of chlorine with adjacent aquifer
  - Chlorinated water shall sit at least 12 hours but less than 24 hrs

Disinfection After Equipment Installation

45

- Circulating the chlorinated water
  - Make pressure tight connection (at least 2 inch diameter) from pump discharge to casing vent
  - Operate pump against throttled discharge
    - This will circulate some water through well while discharging the remainder
  - Test discharge water periodically for chlorine residual
    - When zero residual is measured, pump to waste for 15 minutes
  - Sample for bacteriological
  - Dispose of contaminated or highly chlorinated water properly

Disinfection After Equipment Installation

46

- Bacteriological evaluation (according to AWWA C654)
  - Collect 2 samples (duplicates) not less than 30 minutes apart
  - If any sample comes back total coliform positive
    - Pump well to waste for 15+ minutes, then take duplicate samples not less than 30 minutes apart
    - If still get positive
      - Rechlorinate well using aforementioned steps OR
      - Take corrective action determined by qualified engineer
- If repeated attempts to disinfect the well are unsuccessful, a detailed investigation to determine the cause or source of the contamination should be undertaken

Disinfecting Existing Wells

47

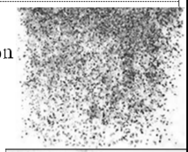
- Wells should be disinfected after repairs and/or parts replacement
  - Swab inside of well casing with nonfoaming detergent
  - Add chlorine to provide 100 mg/L in water
    - Based of well diameter and water depth
  - Add chlorine through hose that is raised and lowered to reach all areas of well, including that portion above the water
  - Clean and disinfect pump and other equipment prior to lowering into well
  - Disinfect well using proper AWWA standards

Sand in Well Systems

48

Sand in Well Systems

49



- Wells in alluvial formations are particularly susceptible to sand production
  - Nearly all wells will produce some sand
- Problems caused by sand
  - Equipment damage: pumps, plumbing fixtures, appliances, water meters, etc.
  - Deposition in distribution leading to decreased carrying capacity
  - Increased customer complaints
- Solutions:
  - Install sand separator
  - Lower flow rate
- Sand concentrations should not exceed 0.3 cu. ft./million gallons

Sand in Well Systems

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Flushing Mains

- Sand in small diameter pipes is typically due to sand in larger mains supplying the water
  - Flush large mains to resolve complaints on small mains
- Must have sufficient velocity to remove sand during main flushing
- Sand may not appear immediately when flushing, but once it does flushing should continue until sand is no longer evident

Vocabulary

A. Alluvial
B. Appurtenance
C. Aquifers
D. Available chlorine
E. Brake horsepower
F. Cone of depression
G. Drawdown
H. Evaporation
I. Foot valve
J. Head
K. Hydrologic Cycle
L. Overdraft
M. Pet cock
N. Pore
O. Porosity
P. Prime
Q. Sounding tube
R. Specific yield
S. Suction lift
T. Transmissivity
U. Transpiration
V. Water hammer
W. Zone of saturation

1. _____ a natural underground layer of porous, water-bearing materials usually capable of yielding a large amount or supply of water
2. _____ the process of evaporation of water into the air and its return to earth by precipitation
3. _____ the process by which water or other liquid becomes a gas
4. _____the process by which water vapor is released to the atmosphere by living plants
5. _____ the soil or rock located below the top of the groundwater table
6. _____ a measure of the spaces or voids in a material or aquifer
7. _____ the quantity of water that a unit volume of saturated permeable rock or soil will yield when drained by gravity
8. _____ the measure of the ability to transmit (as in the ability of an aquifer to transfer water)
9. _____ a very small open space in a rock or granular material
10. _____ the pumping of water from a groundwater basin or aquifer in excess of the supply flowing into the basin
11. _____ the depression, roughly conical in shape, produced in the water table by the pumping of water from a well
12. _____ the drop in the water table or level of water in the ground when water is being pumped from a well.
13. _____ a pipe or tube used for measuring the depths of water
14. _____ a small valve or faucet used to drain a cylinder or fitting
15. _____ a special type of check valve located at the bottom end of the suction pipe on a pump; holds pump’s prime
16. _____ machinery, appliances, structures, or other parts of the main structure necessary to allow it to operate as intended, but not considered part of the main structure

17. _____ the result of opening or closing a valve too quickly causing a change in pressure that can lead to main damage
18. _____action of filing a pump casing with water to remove the air
19. _____ a measure of the amount of chlorine available in chlorinated lime, hypochlorite compounds, and other materials that are used as a source of chlorine
20. _____ the vertical distance, or energy of water above a reference point; may be measured in feet or psi
21. _____ the negative pressure on the suction side of a pump
22. _____ the horsepower required at the top or end of a pump shaft; the energy provided by a motor or other power source
23. _____ relating to mud or sand deposited by flowing water; these deposits my occur after a heavy rain

Answers

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

Section Review Questions

1. What is the purpose of a well?

2. What is the hydrologic cycle?

3. What does porosity measure?

4. Why are there openings in the top of a well?

5. What is the purpose of the well-casing vent?

6. How would you determine the distance down to the water level in a well?

7. What is the purpose of a check valve?

8. What is the purpose of pump control valves?

9. Why must flows be known when chemicals are being applied at a well pumping station?

10. What is the purpose of surge suppressors that are sometimes installed on the discharge side of a booster pump?

11. What is the purpose of and air release and vacuum breaker valve?

12. What is the purpose of an air charger?

13. List three major well maintenance problems.

14. How can overpumping an aquifer damage the aquifer?

15. Encrusting waters are usually (circle one) alkaline/acidic; while corrosive water are usually alkaline/acidic.

16. Why should the use of two or more different types of metals be avoided in a well?

17. What records should be kept regarding a well?

18. What is the purpose of surging?

19. How can the pores in a well screen and the gravel pack around the screen be cleaned?

20. How can encrustation be removed from the well casing and well?

21. How can bacterial growths and slime deposits be removed from well screens?

22. When the yield of a water well declines, what three factors should be investigated to determine the cause?

23. What are the two basic groups of well pumps and the difference between them?

24. When should a well be disinfected?

25. What would you do if repeated attempts to disinfect a well are unsuccessful?

26. Why does the disinfection of existing wells after well or pump repairs require special disinfection methods?

Section Review Questions – Answers

1. to intercept groundwater moving through aquifers and bring water to the surface for use by people

2. he continuous circulation of water on our planet; the process of evaporation of water into the air and its return to the earth by precipitation

3. the openings or voids in a particular soil; quantifies the amount of water that a particular soil type or rock can store

4. to permit the entrance or escape of air or gas and to provide access to the well for taking water level measurements, adding gravel, or for applying disinfection or well cleaning agents

5. to prevent vacuum conditions inside a well by admitting air into the well during the drawdown period when the well pump is first started; to prevent pressure buildup inside the well casing by allowing excess air to escape during the well recovery period after the well pump shuts off

6. inserting a measuring tape into the sounding tube, lowering it down the tube to the water level, and recording the distance; or, air pressure in a sounding line may be used

7. acts as an automatic shutoff valve when the pump stops to prevent draining of the system or the tank being pumped to, and to prevent pressurized water from flowing back down the pump column into the well

8. to eliminate the pipeline surges when the pump is started and stopped

9. in order to calculate the correct chemical feed rate

10. to absorb shock waves in the water system and prevent their transmittal through the line; to prevent water hammer

11. to exhaust large quantities of air very rapidly from a deep well pump column when the pump is started, and to allow air to re-enter the pump column and prevent a vacuum from developing when the pump stops

12. adding air to hydropneumatic tanks

13. overpumping and lowering of the water table
    clogging or collapse of a screen or perforated section
    corrosion or encrustation

14. by reducing storage and production capacity of groundwater systems

15. alkaline; acidic

16. corrosion is usually greatest at the points of contact of the different metals or where they come closest to contact; galvanic corrosion

17. water level measurements in the well before and after pumping; flow rates; water quality samples; length of time pumping; accurate data on pump repairs and causes

18. to open pores in the screen and for cleaning the gravel pack around the screen

19. high velocity jetting

20. acid treatment

21. chlorine treatments

22. the aquifer, the well, and the pump

23. positive displacement pumps - deliver the same volume of water against any head
dynamic pumps - deliver water with the volume or flow varying inversely with the head

24. following development, testing for yield, and before the test pump is removed from the well, or when there is evidence of contamination

25. a detailed investigation to determine the cause or source of the contamination should be undertaken

26. during repair work, deposits of slime, bacterial growth, and other debris are dislodged from the inside surfaces of the well pump column pipe; these deposits can be smeared on the inside surfaces of the well casing which will require swabbing of the inside of the well casing

Section 3

Small Water Plant Operation

SMALL WATER TREATMENT PLANTS

California State University: Sacramento

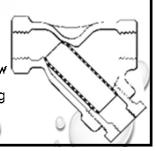
Small Water System Operation and Maintenance

SURFACE WATERS

- Raw water storage
- Diversion works
- Flow measurement
- Disinfection
- Coagulation
- Flocculation
- Settling
- Filtration
- Corrosion Control
- Treated Water Storage
- High service pumps

SURFACE WATER

- Raw Water Storage
  - Slows influent water quality changes
  - Maintain production during source shutdown
- Diversion Works
  - Diversion dam, bar & trash screens, intake pipe/structure, pumps, water conveyance piping, flow control valves
- Flow measurement
  - Should indicate instantaneous flow and total flow
  - Install wye strainer upstream to prevent clogging



SURFACE WATER

- Disinfection
  - Chlorine is recommended disinfectant
  - Prechlorination minimizes organic growth in treatment units
- Coagulation
  - Chemical feed with rapid mix to create microfloc
- Flocculation
  - Slowly mixing water to create larger settleable floc (macrofloc)
- Settling
  - Allows suspended matter to separate from water by gravity

SURFACE WATER

- Filtration
  - Removes remaining suspended matter after sedimentation
- Corrosion control
  - Water stability to minimize corrosion and scaling
- Treated water storage
  - Reservoirs allow treated water to be stored to meet peak demands and provide water during outages
- High service pumps
  - Draws finished water from storage and supply it under pressure

GROUNDWATER

- Iron and manganese control (Fe and Mn)
  - Controlled by oxidation – converting the dissolved form to the insoluble form
    - e.g. liquid ferrous iron (Fe^{2+}) to solid ferric iron (Fe^{3+})
  - Feed oxidizing agent (e.g. chlorine or potassium permanganate) with oxygen to oxidize iron and manganese and form the insoluble (precipitated) form
  - Remove precipitates with sedimentation and/or filtration
- Softening
  - Hardness due to calcium and magnesium ions (Ca and Mg)
  - Softening achieved by ion exchange or chemical precipitation (lime-soda ash softening)

PACKAGE PLANTS

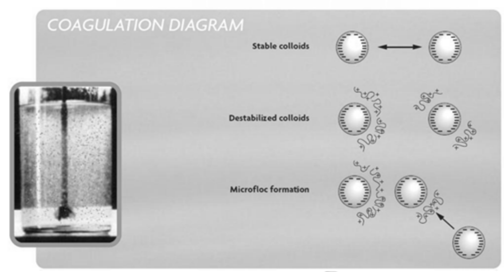
- Most commonly used for filtration of turbid water and removal of dissolved iron and manganese
- Includes all treatment equipment, pumps, chemical feeders, and controls
  - May choose instead to select a custom designed package plant with materials supplied by different manufacturers
- Advantages
  - Design and equipment have already proven effective
  - All bugs eliminated giving purchaser a high degree of confidence and performance
- No plant is completely automatic - still requires maintenance, repair, and occasional process control changes.

COAGULATION & FLOCCULATION

COAGULATION

- Chemical reaction when coagulating chemical is added to water
  - Most common is aluminum sulfate (alum)
- Coagulant reacts physical with fine particles of suspended matter in the water
  - Colloidal particles have a net negative charge causing them to repel each other
    - Zeta Potential
  - Coagulant neutralizes negative charge to destabilize particles allowing them to come together
    - Van Der Waals force
  - Reaction occurs within 2-5 seconds of chemical application

COAGULATION



COAGULATION

- Factors affecting Coagulation
  - Coagulant used and dosage
    - Chemical and dosage must be optimized based on source water
  - Water pH
    - 6.5 – 8.5
  - Alkalinity
    - Must have sufficient alkalinity when using alum
  - Mineral content of water
    - Different minerals will affect coagulation differently
  - Water temperature
    - Better coagulation in warmer water

COAGULATION OPTIMIZATION

- Is the pH after addition of the coagulant the same as when good coagulation occurs?
  - Daily pH records should be maintained
- Is adequate alkalinity present for coagulation reaction?
  - Consider increasing alkalinity to have at least 30 mg/L remaining after chemical reaction complete by adding lime
- Is chemical feeder supplying correct dosage of coagulant?
  - Dry chemical – collect sample of chemical for selected amount of time to compare to set feed rate
  - Solution chemical – use site tube to measure actual feed rate versus set rate

COAGULATION OPTIMIZATION

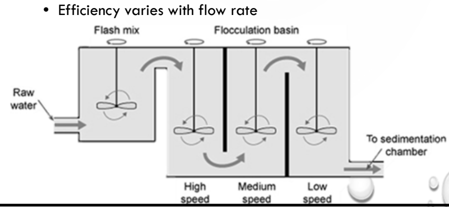
- Does the chemical feeder inject a steady chemical feed into the water?
  - Want consistent pulses vs long interval slug
- Is chemical injector distributing coagulant throughout flow of water?
  - Injectors with multiple-feed orifices better than single orifice
- Is violent rapid mixing provided just after chemical if feed?
  - Install mechanical mixer or relocate injection point to zone of turbulent flow
- Is a coagulant aid needed?
  - Polymer or weighting agent

FLOCCULATION

- Process of slow, gentle mixing of the water to bring smaller floc particles together to form macrofloc
- Mixing must be strong enough to encourage floc formation without settling, but not so strong to break floc apart
- Mechanical mixing
  - Consists of slowly rotating paddles
  - Mixing becomes progressively more gentle as water flows through flocculation basin
  - Preferred method due to flexibility to maintain mixing regardless of flow rate and adjustable agitation rates

FLOCCULATION

- Hydraulic mixing
  - Water flows around obstructions of baffles or through interconnected chambers
  - Disadvantages
    - Less uniform and controllable
    - Efficiency varies with flow rate



FLOCCULATION

- Factors affecting flocculation
  - Degree of mixing
    - Too gentle – particles will not be brought into contact with one another and larger floc will not form
    - Too violent – floc will be torn apart (sheared) preventing size large enough to settle out independently
  - Time
    - Minimum 30 minutes with 45 minutes recommended
    - Minimize short circuiting – water travelling through basin is less than designed time
      - Add baffles or compartments – three recommended
  - Number of particles
    - Clean water is harder to treat due to decreased collisions between particles

FLOCCULATION OPTIMIZATION

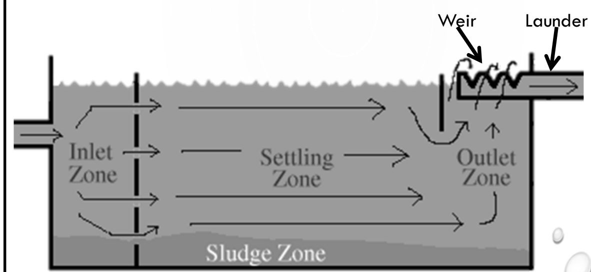
- Correct any deficiencies in the coagulation process
- Check degree of mixing – neither too violent nor too gentle
- Adequate mixing time
  - Do actual flow rates exceed design flows?
- Minimize short circuiting through basin
- Adjust plant to run on a more continuous basis and minimize frequent on/off operation

SEDIMENTATION

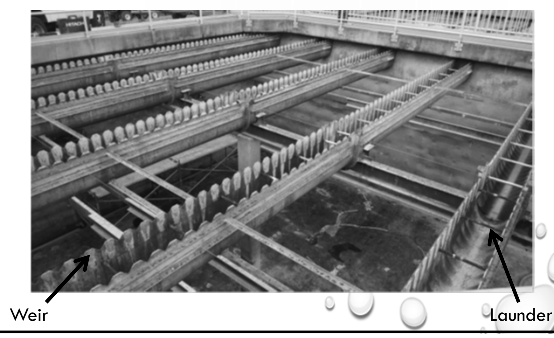
SEDIMENTATION

- Process of holding water in quiet, low-flow condition to allow for settling of suspended particles by gravity
- Tank has four zones
  - Inlet zone – water entering tank distributed across tank with a slow uniform flow velocity
    - Aka influent zone
  - Settling zone – water flows slowly through tank allowing suspended particles to settle out
  - Sludge zone - area where settled material lands in bottom of tank
  - Outlet zone – water is collected in weirs or launders and flows to tank outlet
    - Aka Effluent zone

ZONES OF SEDIMENTATION TANK



SEDIMENTATION



SEDIMENTATION

- Factors affecting sedimentation
  - Time – minimum 4 hours for conventional sedimentation
    - Maybe reduced to 1 hour with tube or plate settlers
  - Suspended matter characteristics – denser material settles faster than light, fluffy particles
    - Determined by coagulation/flocculation process
  - Short-circuiting – long narrow tank more effective than short, wide tank
  - Tank inlet/outlet arrangement – minor changes can cause drastic changes in settling efficiency
    - Inlet should distribute water evenly both horizontally and vertically while avoiding high velocities and eddy currents
    - Outlet should collect water uniformly and near the surface

SEDIMENTATION

- Factors affecting sedimentation
  - Surface overflow rate – lower rate is better than a higher rate
    - aka surface loading rate (SLR)
    - Should be between 0.25 – 0.38 gpm/ft^2
  - Currents in tank – caused by flow inertia, wind action, temperature differences, and poor design;
    - Can cause short-circuiting, resuspend settled particles
  - Water temperature – particles settle faster in warm water than in cold water
    - Cold water is more viscous and creates more resistance
  - Wind – can cause currents and turbulence decreasing settling

SETTLING OPTIMIZATION

- Check coagulation/flocculation process operation
- Decrease rate of flow to lower surface overflow rate and flow velocity
- Improve inlet conditions to reduce velocity, distribute flow uniformly, create uniform flow velocities
  - If more than one tank used, ensure flow divided equally across tanks
- Improve outlet conditions to eliminate velocities
- Remove accumulated sludge
- Cover tank to minimize currents caused by wind and weather
- Recycle sludge to inlet to increase number of particles in water

SEDIMENTATION

- High rate settlers (tube or plate settlers) increase settling efficiency in sedimentation basins
  - Provides surface area for particles to settle on

Tube Settler

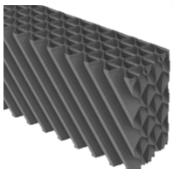
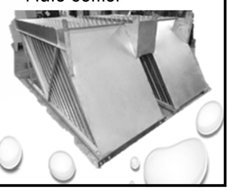


Plate Settler



FILTRATION

FILTRATION

- Process of passing water through a porous bed of material to remove suspended matter from the water
- Two types
  - Gravity filter – water enters tank near the top and flows downward through media under force of gravity
    - Slow sand filter – uses biological process as well as physical straining
  - Pressure filter – water is forced through enclosed tank through filter media under pressure created by an external force

FILTER MEDIA LAYERS

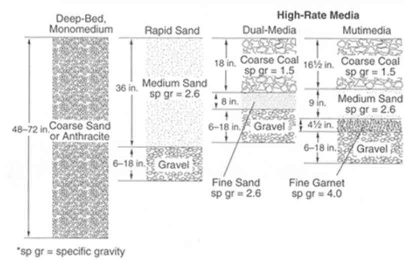


FIGURE 6–8 Comparison of deep-bed, rapid sand, and high-rate filter media

FILTRATION MODES

- Conventional filtration
  - Used with highly variable raw water quality and large volumes of water are required
  - Filtration accomplished by straining and adsorption
  - Includes coagulation, flocculation, & sedimentation prior to filtration
- Direct filtration
  - Used with waters low in turbidity, color, plankton, & coliforms
  - Includes coagulation & flocculation prior to filtration
    - Sedimentation step is omitted
    - This method must be approved by State

These filters are cleaned by backwashing

FILTRATION MODES

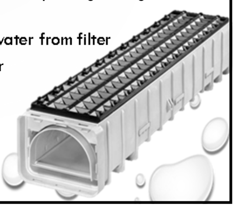
- Diatomaceous earth (precoat) filtration
  - DE is added as a slurry to water being treated and collects on a screening device
  - Water is filtered by passing it through the screening device coated in DE
  - Used where very high particle removal efficiencies required
  - Can be operated as gravity or pressure filter
- Slow sand filtration
  - Particles removed by straining, adsorption, and biological action
  - Majority of particulate removal in top few inches of sand
  - Filter cleaned by remove the top 2 inches of filter media

FILTRATION MEDIA

- Anthracite – hard coal prepared by crushing coal and sieving to get proper size
  - effective size of 0.8 mm to 1.2 mm with a uniformity coefficient not greater than 1.85
  - 1.5 times heavier than water
- Sand – should be hard material like quartz that will not erode or easily dissolve in water
  - effective size of 0.35 mm to 0.55 mm and a uniformity coefficient not greater than 1.70
  - 2.5 times heavier than water
- In 30 inch dual media filter, anthracite should be 18-20 inches deep and sand should be 10-12 inches deep

FILTRATION MEDIA

- Garnet – group of hard, reddish, glassy mineral sands with high density used at bottom of filter
  - When added, this makes filter a multimedia filter
- Underdrain – under filtering media
  - Supports filter media and prevents media passing through bottom of filter
  - Collects filtered water and conveys water from filter
  - Uniformly distributes backwash water across filter bed
    - Most important function



FILTRATION RATES

- Slow sand filters – max 2 gpm/ft^2
  - Assumed Log Removals by Filtration Method
    - Giardia – 2.0 log removal
    - Viruses (crypto) – 2.0 log removal
- High rate filters – max 4 gpm/ft^2
  - Assumed Log Removals by Filtration Method
    - Giardia – 2.5 log removal
    - Viruses (crypto) – 2.0 log removal
  - Includes
    - Rapid sand filters
    - Dual media filters
    - Multimedia filters

FILTRATION

- Filter continuously removes suspended matter while in operation
  - Matter clogs openings and decreases flow through filter
    - Will eventually lead to turbidity breakthrough
    - Head loss will gradually build up
- When terminal head loss is achieved, filter must be cleaned
  - Backwash – reversal of flow direction through filter to flush collected dirt out of media
    - Filter bed expands allowing media grains to scrub against each other and knock off dirt particles
    - Want to leave the filter cleaner but not too clean
      - Ripen filter (filter to waste) before placing filter back in service

FILTRATION

- Backwashing frequency varies from facility to facility
  - Based on time, flow, head loss, and/or effluent turbidity
  - Consistency is key – have a good SOP
- Bed should be expanded to at least 50% its normal depth
  - Not so much that media overflows into troughs
- Minimum backwash rate – 18.75 gpm/ft^2
- Surface wash or subsurface wash required
- Good backwashing increases filter run lengths, finished water production, finished water quality, etc
- Poor backwashing increases finished turbidity, mudball formation, filter short circuiting,

FILTER OPTIMIZATION

- Optimize coagulation, flocculation and sedimentation
  - Settled water turbidity should not exceed 5.0 ntu
- Ensure filtration rate is not higher than designed
- Backwash filter effectively to prevent mudballs
- Operate filter to minimized rapid filter rate changes
  - Eliminate on/off operation
- Inspect media condition frequently
  - Look for loss in depth, mudballs, caking, surface cracks, and mounding or unevenness

FILTER OPTIMIZATION

- Observe filters during backwash and filtering periods to determine condition of underdrain
  - Gravel disturbance and broken underdrains will allow media to pass through in finished water during filtration
  - Mounded media, sand boils, or evidence of uneven upward flow during backwash indicates underdrain issues
- Provide accurate flow and headloss gauges
- Consider feeding a polymer filter aid

- Small Water System Operation and Maintenance
  Office of Water Programs
  Collection of Engineering and Computer Science
  California State University, Sacramento
  Chapter 4

Find more information on the subject of
- Corrosion Control
- Solids-contact Clarification
- Slow Sand Filtration
- Iron and Manganese Control
- Softening
- Operation
- Maintenance

Small Plants – Vocabulary

A. adsorption
B. alkalinity
C. clear well
D. coagulation
E. diatomaceous earth
F. flocculation
G. garnet
H. jar test
I. mudballs
J. precipitate
K. short-circuiting
L. slurry
M. trihalomethanes
N. wye strainer

1. _____ a screen shaped like the letter Y; water flows through upper part of Y and debris is trapped by screen at the fork

2. _____ derivatives of methane in which three halogen atoms are substituted for three of the hydrogen atoms; often formed during chlorination by reactions with natural organic materials in the water

3. _____ the clumping together of very fine particles into larger particles (microfloc) caused by the use of chemicals

4. _____ a reservoir for the storage of filtered water of sufficient capacity to prevent the need to vary the filtration rate with variations in demand; also used to provide chlorine contact time for disinfection

5. _____ capacity of water to neutralize acids; caused by water's content of carbonate, bicarbonate, and hydroxide.

6. _____ laboratory procedure in which varying dosages of coagulant are tested in a series of jars under identical conditions

7. _____ the gathering together of fine particles after coagulation to form larger particles called macrofloc by a process of gentle mixing

8. _____ a condition that in tanks or basins when some of the flowing water entering a tank or basin flows along a nearly direct pathway from the inlet to the outlet

9. _____ an insoluble, finely divided substance that is a product of a chemical reaction within a liquid

10. _____ a fine, siliceous earth composed mainly of the skeletal remains of diatoms

11. _____ a water mixture or suspension of insoluble matter

12. _____ the gathering of a gas, liquid, or dissolved substance on the surface or interface zone of another material

13. _____ a group of hard, reddish, glass, mineral sands made up of silicates of base metals

14. _____ material, approximately round in shape, that forms in filters and gradually increases in size when not removed by the backwashing process

Vocabulary -Answers

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

Small Plants Review Questions

1. How does the storage of raw water in lakes, ponds, or reservoirs help the water treatment plant operator?

2. What information does an operator obtain from a flowmeter?

3. How can a flowmeter be protected?

4. Groundwaters may require what types of treatment?

5. What is the influence of temperature on the coagulation process?

6. How can the alkalinity of the water being treated be increased?

7. What is flocculation?

8. What happens if the flocculation mixing is too strong or too weak?

9. What is the purpose of settling?

10. Short-circuiting is influenced by what factors?

11. How does temperature influence particle settling?

12. Why is sludge recycled to the inlet of the settling tank?

13. What is included in the suspended matter removed by filtration?

14. Why do anthracite and sand stay separated during and after backwashing?

15. What is a mixed media (multimedia) filter?

16. Under what conditions will mudballs form in filters?

Small Plants Review Questions – Answers

1. by slowing the rate of change in water quality due to rainstorms and other factors

2. the instantaneous rate of flow as well as the total quantity of water that has flowed through it

3. by a fine screen or wye strainer installed upstream from the meter to prevent clogging or damage by trash or rocks

4. disinfection, iron and manganese control, and softening

5. the warmer the water, the faster the coagulation chemical reactions

6. by adding lime or soda ash prior to coagulation

7. a process of slow, gentle mixing of the water to encourage the tiny floc in the flocculation basin, but the mixing must not be so strong that it breaks apart the floc particles already formed

8. mixing must be strong enough to prevent premature settling of floc in the flocculation basin, but no so strong that it breaks apart the floc particles already formed

9. to remove as much of the floc and other suspended material as possible before the water flows to the filter

10. (1) the shape and dimensions of the tank, and (2) the inlet and outlet arrangements of the tank

11. the warmer the water, the faster the particles settle

12. to increase the number of particles in the water and improve flocculation of the settling particles

13. mainly particles of floc, soil, and debris; but also living organisms such as algae, bacteria, viruses, and protozoa

14. sand is 2.5 times heavier than water and anthracite is 1.5 times heavier than water

15. a mixed media filter contains three layers of media: garnet, sand, and anthracite

16. mudballs form if backwashing does not effectively clean the media

Section 4

Disinfection

DISINFECTION

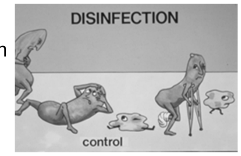
California State University: Sacramento

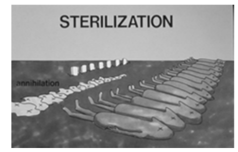
Water Treatment Plant Operation Vol. I

DISINFECTION VS. STERILIZATION

- Disinfection – the destruction of **pathogenic organisms**
  - To prevent waterborne disease outbreaks
  - Destroys only disease-causing organisms
- Sterilization – the destruction of **all organisms** in the water

  Not all microorganisms are bad!





SAFE DRINKING WATER LAWS

- USEPA (US Environmental Protection Agency)
  - Responsible for setting drinking water standards
- SDWA (Safe Drinking Water Act)
  - Sets MCLs (maximum contaminant levels)for substances known to be hazardous to human health
- SWTR (Surface Water Treatment Rule)
  - Requires disinfection for all surface water supply systems to protect against exposure to viruses, bacteria, and *Giardia*

SAFE DRINKING WATER LAWS

- IESWTR (Interim Enhanced Surface Water Treatment Rule)
  - Increase public protection form illness caused by *Cryptosporidium*
- DPBR (Disinfection By-Products Rule)
  - Limits amount of certain potentially harmful disinfection by-products that may remain in drinking water after treatment
- LT2ESWTR (Long Term to Enhanced Surface Water Treatment Rule)
  - Builds upon earlier rules to reduce illness linked with *Cryptosporidium*

FACTORS INFLUENCING DISINFECTION

FACTORS INFLUENCING DISINFECTION

- pH
  - Chlorine disinfects faster at pH of 7 than at pH > 8
  - Hypochlorous acid disassociates at a higher pH
- Temperature
  - Higher temperature means more efficient disinfection
  - Longer contact time required at lower temperatures
  - Chlorine will dissipate faster in warmer waters
- Microorganisms
  - Number and type greatly influence disinfection effectiveness
  - Cysts and viruses can be very resistant to disinfection

FACTORS INFLUENCING DISINFECTION

- Turbidity
  - Excessive turbidity greatly reduces disinfection efficiency
  - Organic Matter
    - Organics can consume great amounts of disinfectants while forming unwanted compounds such as disinfection by-products
    - Reactions with organics and other reducing agents will significantly reduce the amount chemical available for disinfection
  - Inorganic matter
    - Ammonia can combine with disinfectant chemical to form side compounds

FACTORS INFLUENCING DISINFECTION

- Reducing Agents
  - Any substance that will readily donate electrons
  - Demand for chlorine by reducing agents must be met before chlorine becomes available to accomplish disinfection
  - Inorganic reducing agents
    - Hydrogen sulfide gas (H_2S)
    - Ferrous ion (Fe^{2+})
    - Manganous ion (Mn^{2+})
    - Ammonia (NH_3)
    - Nitrite ion (NO_2^-)

PROCESS OF DISINFECTION

PURPOSE OF PROCESS

- To destroy harmful organisms
- Physical
  - Removes the organisms from the water, or
  - Introduces motion that will disrupt the cells' biological activity and kill or inactivate them
- Chemical
  - Alter the cell chemistry causing microorganism to die
  - Most widely used is chlorine because it is easily obtained and leaves a measurable residual chlorine

AGENTS OF DISINFECTION

- Physical Means of Disinfection
  - Ultraviolet Rays (UV)
    - Rays must come in contact with each microorganism
    - Lack of measureable residual
  - Heat
    - Rolling boil for 5 minutes
  - Ultrasonic Waves
    - Sonic waves destroy microorganisms by vibration

AGENTS OF DISINFECTION

- Chemical Disinfectants
  - Iodine
    - Limited to emergency use due to high cost and negative health effects
  - Bromine
    - Very limited due to handling difficulties
  - Bases (sodium hydroxide and lime)
    - High pH leaves a bitter taste in water
  - Ozone
    - High costs, lack of residual, difficult to store, high maintenance requirements

AGENTS OF DISINFECTION

- Chemical Disinfectants
  - Chlorine -- Cl_2
    - 100% pure
    - gas
  - Calcium hypochlorite -- $Ca(Ocl)_2$
    - 65% pure
    - solid
    - HTH – high test hypochlorite
  - Sodium hypochorite -- NaOCl
    - 5-15% pure
    - Liquid
    - Bleach

CHLORINE (Cl_2)

- Properties of Chlorine
  - Greenish-yellow gas
  - 2.5 times heavier than air
  - Volume of gas will increase by almost 90% when temperatures rise
  - Liquid expands to 460 times the volume as a gas
  - Can support combustion

CHLORINE (Cl_2)

- Reaction with Water

$$Cl_2 + H_2O \rightarrow \underset{\text{hypochlorous acid}}{HOCl} + \underset{\text{hydrochloric acid}}{HCl}$$

Lowers pH (HCl)

  - Free chlorine combines with water to form hypochlorous acid
    - Most effective disinfectant
    - Dissociates at higher pH (greater than 7)

$$\underset{\text{hypochlorous acid}}{HOCl} \rightarrow H^+ + \underset{\text{hypochlorite ion}}{OCl^-}$$

  - Hypochlorous acid has a much higher disinfection potential than hypochlorite ion
  - At pH = 7.5, of the chlorine present 50% will be HOCl and 50% will be OCl^-

CHLORINE (Cl_2)

- Hydrogen sulfide and ammonia are inorganic reducing agents
  - Hydrogen sulfide reacts with chlorine to form sulfuric acid and elemental sulfur
    - Causes odor problems
  - Ammonia reacts with chlorine to form chloramines
    - As ammonia concentration increases, the disinfectant power of chlorine decreases
  - Organics react with chlorine to form trihalomethanes (carcinogens)

HYPOCHLORITE (OCl^-)

- Reactions with Water
  - May be applied in the form of calcium hypochlorite ($Ca(OCl)_2$) or sodium hypochlorite (NaOCl)

$$Ca(OCl)_2 + H_2O \rightarrow \underset{\text{hypochlorous acid}}{HOCl} + \underset{\text{calcium hydroxide}}{Ca(OH)_2}$$

$$NaOCl + H_2O \rightarrow \underset{\text{hypochlorous acid}}{HOCl} + \underset{\text{sodium hydroxide}}{NaOH}$$

  - Raises pH due to OH^- ion
  - If is $Ca(OCl)_2$ injected at the same point of as sodium fluoride, a severe crust can form at injection point

CHLORINE DIOXIDE (ClO_2)

- May be used as a primary disinfectant
  - Not affected by ammonia
  - Very effective disinfectant at higher pH levels
  - Reacts with sulfide compounds to help remove and eliminate their characteristic odors
  - Can control phenolic tastes and odors
  - Effective oxidizing agent with iron and manganese
  - Does not form carcinogenic compounds from treating organics

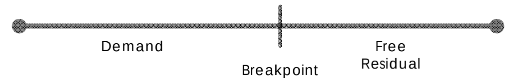
CHLORINATION

- Disinfection Action
  - Chlorine demand - the point where the reaction with organic and inorganic materials (aka reducing agents) stops
  - Chlorine residual – the total of all the compounds with disinfecting properties plus any remaining free chlorine
  - Chlorine dose – the amount of chlorine needed to satisfy the chlorine demand and the amount of chlorine residual needed for disinfection

Dose = Demand + Residual

BREAKPOINT CHLORINATION

- The process of adding chlorine to water until the chlorine demand has been satisfied
  - Further additions of chlorine will result in a chlorine residual that is directly proportional to the amount of chlorine added beyond the breakpoint



  - Total chlorine dose = residual + demand

BREAKPOINT CHLORINATION

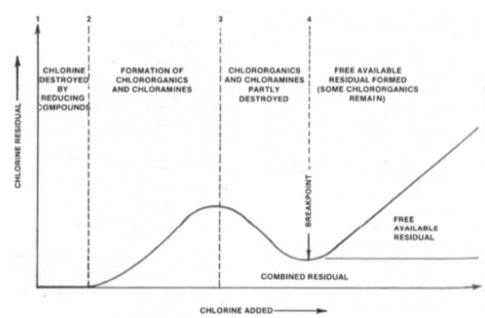


Fig. 7.2 Breakpoint chlorination curve

CHLORAMINATION

- Chloramines have been used as an alternative disinfectant for over 70 years
- An operator's decision to use chloramines depends on several factors
- However, chloramination alone is not an approved method of disinfection in the state of Tennessee

CHLORINE RESIDUAL TESTING

- Chlorine is effective in control biological agents and eliminating coliform bacteria
- To ensure adequate control of coliform aftergrowth, a chlorine residual of 0.2 mg/L in the distribution system can be a good indicator
  - A lack of this residual could indicate the presence of a heavy contamination

CHLORINE RESIDUAL TESTING

- Critical Factors
  - Effectiveness of upstream treatment processes
  - Injection point and method of mixing
  - Temperature
    - The higher temp, the more rapid the disinfection
  - Dosage and type of chemical
    - The higher the dose, the faster the disinfection
  - pH
    - The lower the pH, the better the disinfection
  - Contact time
    - Longer contact time has better disinfection
  - Concentration
    - Chlorine residual

CT VALUES

“kill” is proportional to C x T

- Destruction of organisms depends on the concentration of chlorine added (C) and the amount of time the chlorine is in contact with the organisms (T)
- Inversely proportional
  - If one is decreased, the other must be increased to ensure that “kill” remains the same

POINTS OF CHLORINE APPLICATION

- Prechlorination
  - Application of chlorine ahead of any other treatment processes
  - Benefits
    - Control of algal and slime growths
    - Control of mudball formation
    - Improved coagulation
    - Reduction of tastes and odors
    - Increased chlorine contact time
    - Increased safety factor in disinfection of heavily contaminated waters

POINTS OF CHLORINE APPLICATION

- Postchlorination
  - Application of chlorine after the water has been treated but before it enters the distribution system
  - Primary point of disinfection
- Rechlorination
  - Practice of adding chlorine in the distribution system
  - Common when distribution system is long or complex
- Wells
  - Good practice whenever wells are used for public water supplies

POINTS OF CHLORINE APPLICATION

- Mains
  - After initial installation and any repairs
- Tanks and Reservoirs
  - To resolve specific problems
  - After initial installation, repairs, maintenance, repainting, and cleaning
- Water Supply Systems
  - i.e. Small water systems

OPERATION OF CHLORINATION EQUIPMENT

HYPOCHLORINATORS

- A piece of equipment used to feed liquid chlorine solutions (bleach)
- Consists of chemical solution tank, diaphragm-type pump, power supply, water pump, pressure switch, water storage tank

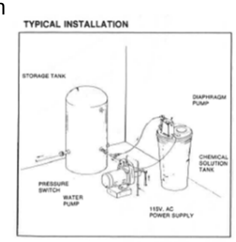


Fig. 7.7 Typical hypochlorinator installation
(Permission of Wallace & Tiernan Division, Pennwalt Corporation)

HYPOCHLORINATORS

- 2 methods of feeding
  - Directly pumped into water
  - Pump through an ejector (injector)
    - Draws in additional water for dilution of solution

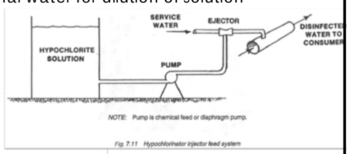


Fig. 7.11 Hypochlorinator injector feed system

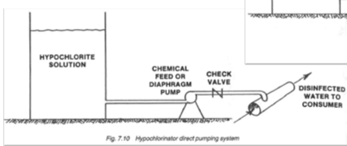


Fig. 7.10 Hypochlorinator direct pumping system

CHLORINATORS

- Chlorine gas may be removed from chlorine containers by a valve and piping arrangement
- Chlorine gas is controlled, metered, and introduced into a stream of injector water, and then is conducted as a solution to the point of application
- Safety
  - Protective clothing: gloves and rubber suit
  - Self-contained pressure-demand air supply system (SCBA)
  - Chlorine leak detector set at floor level
    - Warning device located outside chlorine room

CHLORINATORS PARTS

- Ejector – creates the vacuum that moves the chlorine gas (also called injector or eductor)
  - Fitted with Venturi valve
- Check valve assembly – prevents water from back-feeding as the water moves through ejector
- Rate valve – controls the flow rate at which chlorine gas enters the chlorinator
- Diaphragm assembly – connects directly to the inlet valve of the vacuum regulator

CHLORINE CONTAINERS

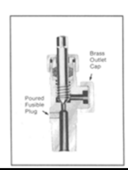
- Plastic
  - Commonly used for storage of hypochlorite solution
  - Should be large enough to hold 2-3 days' supply
    - Fresh solution should be prepared every 2-4 days
    - Sodium hypochlorite will lose 2-4% concentration per month at room temperature
    - Recommended shelf life of 60-90 days

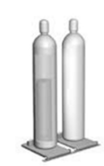
CHLORINE CONTAINERS

- Steel Cylinders
  - Safety for handling and storing
    - Move cylinders with a properly balanced hand truck
    - Can be rolled in a vertical position
    - Always replace the protective cap when moving a cylinder
    - Keep cylinders away from direct heat and direct sun
    - Transport and store cylinders in an upright position
    - Store empty cylinders separate from full cylinders
      - Never store near turpentine, ether, anhydrous ammonia, finely divided metals, hydrocarbons, or other materials that are flammable
    - Remove outlet cap from cylinder and inspect outlet threads
    - Test chlorine cylinders at 800 psi every 5 years

CHLORINE CONTAINERS

- Steel Cylinders
  - Contain 100 to 150 pounds
  - Fusible plug is placed in the valve below the valve seat
    - Safety device to prevent buildup of excessive pressures
    - Melts at 158°-165°F (70°-74°C)





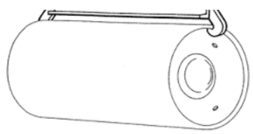
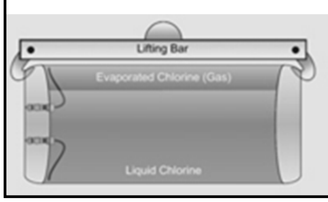
CHLORINE CONTAINERS

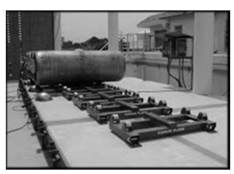
- Ton Tanks
  - Loaded weight of about 3,700 pounds
  - Openings for fusible plugs and valves
    - 2 operating valves
    - 6 fusible plugs (3 on each end)



CHLORINE CONTAINERS

- Ship ton tanks by rail in multiunit cars, truck or semitrailer
- Handle ton tanks with a suitable lift clamp or in conjunction with a hoist or crane
- Lay ton tanks on their sides
- Do not stack
- Separate tanks by 30 inches for access in case of leaks
- Place ton tanks on trunnions that are equipped with rollers
  - In case of a leak, tank can be rolled so that the leaking chlorine escapes as a gas not a liquid
- Use locking devices to prevent ton tanks from rolling while connected

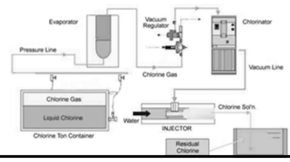


REMOVING CHLORINE FROM CONTAINERS

- Whenever performing any work or maintenance on chlorine cylinders, a self-contained breathing apparatus (SCBA)should be worn or at least readily available
- Greater than maximum feed rate will result in freezing and a decreased rate of delivery
  - 50 lb cylinder = 40 lbs/day
  - Ton cylinder = 400 lb/day
    - With evaporator = 9,600 lb/day
- Frosting may cause gas to condense to liquid which could plug the chlorine supply lines

REMOVING CHLORINE FROM CONTAINERS

- Ton Tanks
  - Must be placed on their sides with valves in vertical positions to allow either chlorine gas or liquid to be removed
    - Top valve to remove chlorine gas
    - Bottom valve to remove liquid chlorine
    - Must use an evaporator – used to convert liquid chlorine to gaseous chlorine

MAINTENANCE

CHLORINE LEAKS

- Chlorine leak can be smelled at concentrations as low as 3 ppm
  - Detectors can detect 1ppm or less
- Always work in pairs when looking for and repairing leaks
- If leak is large, all persons in adjacent areas should be warned and evacuated

CHLORINE LEAKS

- Any new or repaired system should be cleaned, dried, and tested for leaks

- Ammonia solution on a piece of cloth held near a chlorine leak will produce a white vapor
  - Use concentrated ammonia solution of 28-30% ammonia
  - A squeeze bottle filled with ammonia water to dispense vapor may also be used
- If leak is in the equipment, close the valves at once

CHLORINE LEAKS

- If leak is in cylinder, use emergency repair kit
  - For 150 lb cylinder, Emergency Repair kit A
  - For ton cylinder, Emergency Repair kit B
  - For railroad car, Emergency Repair kit C

CHLORINE LEAKS

- If chlorine leaking as a liquid, rotate cylinder so leak is on top
  - Chlorine is escaping only as a gas
- If prolonged or unstoppable leak, emergency disposal should be provided
  - Chlorine may be absorbed into solutions of caustic soda, soda ash, or agitated hydrated lime
- Never put water on a chlorine leak
  - By-product (sulfuric acid) will make the leak larger
- Leak around valve stem can be stopped by closing the valve or tightening the packing gland nut

CHLORINE LEAKS

- Leaks at valve discharge outlet can often be stopped by replacing the gasket or adapter connection
- Leaks at fusible plugs and cylinder valves usually require special handling and emergency equipment
- Pinhole leaks in the walls of cylinders can be stopped by using a clamping pressure saddle with a turnbuckle available in repair kits
  - Temporary fix
- A leaking container must not be shipped
- Do not accept delivery of containers showing evidence of leaking, stripped threads, etc.

MEASUREMENT OF CHLORINE RESIDUAL

METHODS OF MEASURING CHLORINE RESIDUAL

- Amperometric titration
- DPD tests
- All subpart H systems (surface water systems and groundwater systems under the influence of surface water) must provide disinfection
- Must collect residual chlorine sample at the same frequency and location as total coliform samples

METHODS OF MEASURING CHLORINE RESIDUAL

- Amperometric titration
  - A means of measuring concentrations of certain substances in water based on the electric current that flows during a chemical reaction
  - 1. place a 200 mL sample of water in titrator
  - 2. Start the agitator
  - 3. Add 1 mL of pH 7 buffer
  - 4. Titrate with phenylarsene oxide solution (PAO)
  - 5. End point is reached when one drop will cause a deflection on the microammeter and the deflection will remain
  - 6. mL of PAO used in titration is equal to mg/L of free chlorine residual

METHODS OF MEASURING CHLORINE RESIDUAL

- DPD tests
  - A method of measuring the chlorine residual in water
  - N,N-diethyl-p-phenylene-diamine
  - The residual may be determined by either titrating or comparing a developed color with color standards
    1. Collect a sample
       - Typically 10 mL or 25 mL
    2. Zero instrument with sample blank
    3. Add color reagent
    4. Read colored sample in spectrophotomer or colorimeter
  - "False positive" can occur when sample contains a combined chlorine residual

CHLORINE SAFETY PROGRAM

CHLORINE HAZARDS

- Chlorine gas is 2.5 times heavier than air
  - Extremely toxic
  - Corrosive in moist atmospheres
  - Very irritating to mucous membranes of the nose, throat, and lungs

Effect	Cl_2 concentration (ppm)
Slight symptoms after several hours' exposure	1
Detectable odor	0.3-3.5
Noxiousness (harmful)	5
Throat irritation	15
Coughing	30
Dangerous from ½ to 1 hour	40
Death after a few deep breaths	1,000

CHLORINE PPE

- Every person should be trained in the use of self-containing breathing apparatus (SCBA), methods of detecting hazards, and should know what to do in case of emergencies
- Clothing exposed to chlorine can be saturated with chlorine, which will irritate the skin if exposed to moisture or sweat
- Self-contained air supply and positive pressure breathing equipment must fit and be used properly
- Wear protective clothing to enter an area containing a chlorine leak
  - Chemical suit will prevent chlorine from contacting the sweat on the body and forming hydrochloric acid

FIRST-AID MEASURES

- Mild chlorine exposure
  - Leave contaminated area
  - Move slowly, breathe lightly without exertion, remain calm, keep warm, and resist coughing
  - If clothing has been contaminated, remove as soon as possible
  - If slight irritation, immediate relief can come from drinking milk

FIRST-AID MEASURES

- Extreme Chlorine Exposure
  - Follow established emergency procedures
  - Always use proper safety equipment; do not enter area without self-contained breathing apparatus
  - Remove patient from affected area immediately
  - First-aid
    - Remove contaminated clothes
    - Keep patient warm and cover with blankets
    - Place patient in comfortable position on back
    - Administer oxygen if breathing is difficult
    - Perform mouth-to-mouth resuscitation if breathing seems to have stopped
    - If chlorine has got in eyes, flush with large amounts of water immediately (at least 15 minutes)

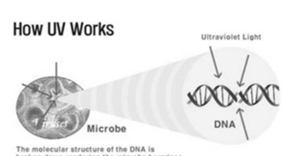
HYPOCHLORITE SAFETY

- Wash spills with large volumes of water
- Hypochlorite can damage eyes and skin upon contact
  - Immediately wash affected are thoroughly with water
- Nonflammable, however can cause a fire when comes in contact with organics

DISINFECTION USING ULTRAVIOLET (UV) SYSTEMS

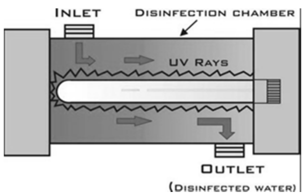
USES OF UV SYSTEMS

- Ultraviolet light – band of electromagnetic radiation just beyond the visible light spectrum
  - UV light absorbed by cells of microorganisms damages the genetic material to cease growth or reproduction



TYPES OF UV LAMPS

- Based on internal operating design
  - Low-pressure, low-intensity
  - Low-pressure, high-intensity
  - Medium-pressure, high-intensity



LOW PRESSURE UV LAMPS

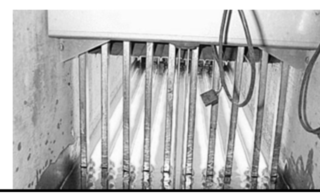
- Source of UV energy in majority of systems
- Last between 8,000 and 10,000 hours
- Operate between 40º and 60ºF
- Generate light by transforming electrical energy into UV radiations
- Emits light at wavelength 253.7 nm
- Each lamp protected by quartz sleeve with watertight electrical connections

LOW PRESSURE UV LAMPS

- Lamp assemblies mounted in a rack(s) that are immersed in flowing water
- Can be enclosed in a vessel or in an open channel
  - Enclosed in vessels in pressure systems
- Placed either horizontal and parallel to flow or vertical and perpendicular to flow
- Number of lamps determines water depth in channel

SAFETY

- UV lamp can burn eyes
- Never look into uncovered parts of the UV chamber without protective glasses
- Lamps contain mercury vapor that will be released of lamp breaks



OPERATION

- Water level over lamps must be maintained to ensure all microorganisms are exposed and to prevent short circuiting
- Water level control device must be regulated by the operator to:
  - Minimize variation of the channel's water level
  - Maintain the channel's water level at a defined level
  - Keep the UV lamps submerged at all times
  - Prevent excessive water layer thickness above the top lamp row

OPERATION

- Light must be intense enough to penetrate pathogens' cell walls
  - Intensity affected by the condition of the UV lamps and the quality of the water
  - An old or dirty lamp has a reduced UV light intensity
  - High turbidity inhibits light transmission, reducing the disinfecting power in proportion to its distance from the light source
  - High TSS inhibits light transmission and shields bacteria protecting them from disinfection
- Low UV light intensity will produce a low level of disinfection

OPERATION

- UV Dose Calculation
  - Intensity of UV radiation and contact time determine the UV dose and, therefore, the effectiveness
  - Expressed as mJ/sq cm (milli-joules per square centimeter)
  - Use worse case intensity for calculation (farthest point from UV)
- Channel Volume Calculation
  - Refers to the irradiated volume of the UV reactor
    - Volume of bacteria exposed to UV radiation
  - Fixed calculation

OPERATION

- Routine Operations Tasks
  - Check UV monitors for UV transmission
  - Routinely clean the UV lamps
- Wiping Systems
  - Should be observed to ensure proper operation of the wiping action of a bank and the proper wiping cycle
- Monitoring Lamp Output Intensity
  - Lamp output declines with use
  - Lamps should be replaced with output no longer meets standards or burn out

OPERATION

- Monitoring Influent and Effluent Characteristics
  - Must maintain velocities and low turbidity levels
    - Suspended particles shield microorganisms from UV light
    - Flows should be somewhat turbulent to ensure exposure to all microorganisms, but controlled so that water is exposed for long enough for disinfection to occur
  - Bacteriological tests must be performed frequently since there is no residual left by UV
- Emergency Alarms
  - UV systems require extensive alarm systems to ensure complete disinfection

MAINTENANCE

- Routine Maintenance
  - Check UV monitor for reduction in lamp output
  - Monitor process for major changes
  - Check for fouling of the quartz sleeves
  - Check that all UV lamps are energized
  - Monitor reports to determine UV lamp replacement interval
  - Check quartz sleeves for discoloration
  - Dewater and hose down UV channel if algae and other attached biological growths form on walls and floor

MAINTENANCE

- Quartz Sleeve Fouling
  - Occurs when cations attach to protein and colloidal matter that crystallizes on the quartz sleeves
  - This will decrease the intensity of the UV light
- Sleeve Cleaning
  - Frequency depends on the quality of water being treated and treatment chemicals used
  - Best done by dipping bulbs an inorganic acid solution for 5 minutes
    - i.e. Nitric acid (50%) or phosphoric acid (5-10%)

MAINTENANCE

- UV lamps
  - Service life ranges from 7,500 – 20,000 hours
  - Depends on
    - Level of suspended solids
    - Frequency of on/off cycles
    - Operating temperature of lamp electrodes
  - Lamp output drops 30-40% in first 7,500 hours
  - Lamp electrode failure is most common cause of lamp failure
  - Do not throw used lamps in garbage can
    - Must be disposed properly due to mercury content

OZONE

Introduction to Water Treatment

OZONE (O_3)

- Bluish toxic gas with pungent odor
- Alternative disinfectant
- Very strong oxidant and virucide (kills viruses)
- Must be generated on site
- Generated by passing an electrical current through pure oxygen

$$O_2 + \text{Energy} \rightarrow O + O$$

$$O + O_2 \rightarrow O_3$$

OZONE (O_3)

- Effectiveness of disinfection depends on
  - Susceptibility of the target organisms
  - Contact time
  - Concentration of the ozone
- Because ozone is consumed quickly, it must be exposed to the water uniformly
- Residual ozone measured by the iodometric method
- Dissolved ozone measured by Indigo test

EQUIPMENT

- Consists of 4 major parts
  - Air preparation unit
  - Electrical power unit
  - Ozone generator
  - Contactor

EQUIPMENT

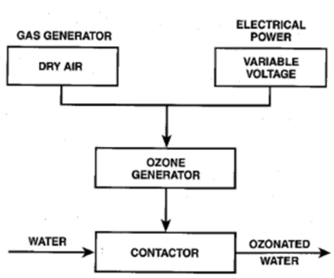


Fig. 7.47 Ozonation equipment

EQUIPMENT

Air preparation

- When air is used as the feed gas for an ozone generator, it must be extremely dry
- The preparation unit usually consists of a commercial air dryer with a dew point monitoring system
  - This is the most critical part of the system
- Air should be clean and dry with a dew point below -51°C (-60°F)

EQUIPMENT

Electrical Power Units

- Usually a very special electrical control system
- Most common unit provides low frequency, variable voltage
- For large installations, medium frequency, variable voltage is used
  - Reduces power costs
  - Allows for higher ozone output

EQUIPMENT

Ozone Generator

- Consists of a pair of electrodes separated by a gas space and a layer of glass insulation
- Air passes through the empty space
- Electrical discharge occurs across the gas space and ozone is formed

Oxygen from air + Electrical voltage → Ionized oxygen + Heat
O_2 + electricity → 2(O)

Ionized oxygen + Non-ionized oxygen → Ozone
2(O) + 2(O_2) → 2 (O_3)

EQUIPMENT

Ozone Contactor

- Mixing chamber for the ozone rich material and the water
- Ozone has a very short life
- Must be evenly and efficiently introduced to the water to be treated
  - Critical to the success of the system

EQUIPMENT

Types of Ozone Contactors

- Turbine mixers
- Injectors
- Packed columns
- Spray chambers
- Fine-bubble diffusion
  - Most common
  - Small bubbles rise through the tank transferring the ozone to the water

OZONE ADVANTAGES

- More effective than chlorine in destroying viruses
- No harmful residuals after ozonation
- No regrowth of microorganisms
- Removes color, tastes, and odors
- Oxidizes iron, manganese, sulfides and organics

OZONE LIMITATIONS

- Low dosage may not effectively inactivate some viruses, spores, and cysts
- Complex technology requiring complicated equipment
- Ozone if very reactive and corrosive require corrosion resistant materials
- Ozone is very irritating and possibly toxic
- The cost of treatment can be relatively high in capital and power costs
- Cannot be used as sole means of disinfectant in Tennessee due to Cl_2 residual requirements
- Can combine with bromide to form bromate
  - A carcinogen

APPLICATIONS OF OZONE

- Ozone may be used for more than just disinfection or viral inactivation
  - When used prior to coagulation
    - Treats Fe and Mn, helps flocculation, and removes algae
  - If applied before filtration
    - Oxidizes organics, removes color, and treats tastes and odors

MAINTENANCE

- Inspect electrical equipment and pressure vessels monthly
- Conduct a yearly preventive maintenance program
  - Should be done by a factory representative or an operator trained by the manufacturer
- Lubricate moving parts according to manufacturer's recommendations

SAFETY

- Ozone is a toxic gas and is a hazard to plants and animals
- When ozone breaks down in the atmosphere, the resulting pollutants can be very harmful
- Ozone contactors must have a system to collect ozone off-gas.
  - Ozone generating installations must include a thermal or catalytic ozone destroyer

Fleming Training Center

Pipe Disinfection Formulas for <u>50 mg/L</u> of HTH

If a pipe is of size not listed below, the following formula will give the calculations needed to find the amount of HTH needed, if the length of line is given:

Calculation Formula = $0.000026007(X)^2(L)$

L= the length of the line in feet,
X = the diameter in inches

Or, Use the following Chart, if Pipe Diameter is listed

DIAMETER (INCHES)	LBS OF HTH
6	0.000935(L)
8	0.00166(L)
10	0.0026(L)
12	0.00374(L)
14	0.00509(L)
16	0.00665(L)
20	0.01038(L)
C24	0.01495(L)

Contact Amanda Carter At Fleming Training Center

(615) 898-6507

Disinfection Vocabulary

A. Amperometric Titration
B. Bacteria
C. Breakpoint Chlorination
D. Carcinogen
E. Chlorination
F. Chlorine Demand
G. Chlorine Requirement
H. Chlorine Residual
I. Chlororganic
J. Colorimetric Measurement
K. Combined Available Chlorine
L. Combined Available Chlorine Residual
M. Combined Chlorine
N. Combined Residual Chlorination
O. DPD
P. Dew Point
Q. Disinfection
R. Eductor
S. Enteric
T. Free Available Residual Chlorine
U. HTH
V. Hydrolysis
W. Hypochlorination
X. Hypochlorite
Y. IDLH
Z. MPN
AA. Oxidation
BB. Oxidizing Agent
CC. Pathogenic Organisms
DD. Postchlorination
EE. Potable Water
FF. Prechlorination
GG. Precursor, THM
HH. Reagent
II. Reducing Agent
JJ. Reliquefaction
KK. Sterilization
LL. Titrate
MM. Total Chlorine
NN. Total Chlorine Residual
OO. Trihalomethanes
PP. Turbidity
QQ. Ultraviolet

_____ 1. The Most Probable Number of coliform group organisms per unit volume of sample water

_____ 2. Any substance which tends to produce cancer in an organism

_____ 3. A chemical reaction in which a compound is converted into another compound by taking up water.

_____ 4. Any substance that will readily donate electrons

_____ 5. The application of chlorine to water to produce combined available chlorine residual

_____ 6. A hydraulic devise used to create a negative pressure by forcing a liquid through a restriction, such as a Venturi.

_____ 7. Organic compounds combined with chlorine

_____ 8. Organisms capable of causing diseases in a host

_____ 9. The total concentration of chlorine in water, including the combined chlorine and the free available chlorine

_____ 10. Pertaining to a band of electromagnetic radiation just beyond the visible light spectrum; used to disinfect water

_____ 11. Addition of chlorine to water until the chlorine demand has been satisfied; additional chlorine beyond this point will result in a free chlorine residual

_____ 12. Immediately Dangerous to Life or Health; the atmospheric concentration of any toxic, corrosive or asphyxiant substance that poses and immediate threat to life or would cause irreversible or delayed adverse health effects

_____ 13. The amount of chlorine that is needed for a particular purpose

_____ 14. The addition of oxygen, removal of hydrogen, or the removal of electrons from an element or compound

_____ 15. The removal or destruction of all microorganisms

_____ 16. The cloudy appearance of water caused by the presence of suspended and colloidal matter

_____ 17. A pure chemical substance that is used to make new products or is used in chemical tests to measure, detect, or examine other substances

_____ 18. The application of hypochlorite compounds to water for the purpose of disinfection.

_____ 19. The sum of the chlorine species composed of free chlorine and ammonia

_____ 20. The total chlorine, present as chloramine or other derivatives, that is present in a water and is still available for disinfection and for oxidation of organic matter

_____ 21. The application of chlorine to water generally for the purpose of disinfection

_____ 22. The addition of chlorine at the headworks of the plant prior to other treatment processes mainly for disinfection and control of tastes, odors, and aquatic growths

_____ 23. That portion of the total available residual chlorine composed of dissolved chlorine gas, hypochlorous acid, and or hypochlorite ion remaining in water after chlorination.

_____ 24. A method of measuring the chlorine residual in water

_____ 25. An substance, such as oxygen or chlorine, that will readily add electrons

_____ 26. The return of a gas to the liquid state e.g. a condensation of chlorine gas to return it to its liquid form by cooling

_____ 27. The concentration of residual chlorine that is combined with ammonia, organic nitrogen, or both in water as a chloramine and is still available to oxidize organic matter and kill bacteria

_____ 28. The difference between the amount of chlorine added to water and the amount of residual chlorine remaining after a given contact time

_____ 29. Living organisms, microscopic in size, which usually consist of a single cell

_____ 30. The addition of chlorine to the plant effluent, following plant treatment, for disinfection purposes

_____ 31. The total amount of chlorine residual present in a water sample after a given contact time

_____ 32. Of intestinal origin, especially applied to wastes or bacterias

_____ 33. Water that does not contain objectionable pollution, contamination, minerals, or infective agents and is considered satisfactory for drinking

_____ 34. The temperature to which air with a given quantity of water vapor must be cooled to cause condensation of the vapor in the air

_____ 35. A means of measuring unknown chemical concentrations in water by measuring a sample's color intensity

_____ 36. A means of measuring concentrations of certain substances in water based on the electric current that flows during a chemical reaction

_____ 37. A chemical solution of known strength is added drop by drop until a certain color change, precipitate, or pH change in the sample is observed (end point)

_____ 38. Natural organic compounds found in all surface and groundwaters that may react with halogens such as chlorine

_____ 39. Calcium hypochlorite. $Ca(OCl)_2$

_____ 40. The process designed to kill or inactivate most microorganisms in water, including essentially all pathogenic bacteria

_____ 41. The concentration of chlorine present in water after chlorine demand has been satisfied

_____ 45. Derivatives of methane in which three halogen atoms are substituted for three of the hydrogen atoms

_____ 43. Chemical compounds containing available chlorine

Answers

1. Z	12. Y	23. T	34. P
2. D	13. G	24. O	35. J
3. V	14. AA	25. BB	36. A
4. II	15. KK	26. JJ	37. LL
5. N	16. PP	27. L	38. GG
6. R	17. HH	28. F	39. U
7. I	18. W	29. B	40. Q
8. CC	19. M	30. DD	41. H
9. MM	20. K	31. NN	42. OO
10. QQ	21. E	32. S	43. X
11. C	22. FF	33. EE	

Disinfection
Review Questions

1. What are pathogenic organisms?

2. What is disinfection?

3. Drinking water standards are established by what agency of the United States government?

4. MCL stands for what words?

5. How does pH influence the effectiveness of disinfection?

6. How does the temperature of the water influence disinfection?

7. What two factors influence the effectiveness of disinfection on microorganisms?

8. List the physical agents that have been used for disinfection (chlorine is not a physical agent).

9. List the chemical agents other than chlorine that have been used for disinfection.

10. What is a major limitation to the use of ozone?

11. How is the chlorine dosage determined?

12. List two organic reducing chemicals with which chlorine reacts rapidly.

13. What does chlorine produce when it reacts with organic matter?

14. How do chlorine gas and hypochlorite influence pH?

15. How does pH influence the relationship between HOCl and OCl^-?

16. What is breakpoint chlorination?

17. List the two most common points of chlorination in a water treatment plant.

18. Under what conditions should waters not be prechlorinated?

19. What are the benefits of prechlorination?

20. List the major parts of a typical hypochlorinator system.

21. What are the two common methods of feeding hypochlorite to the water being disinfected?

22. What type of container is commonly used to store hypochlorite?

23. How large a supply of hypochlorite should be available?

24. What is the purpose of the fusible plug?

25. What is removed by the upper and lower valves of ton chlorine tanks?

26. Why are one-ton tanks placed on their sides with the valves in a vertical position?

27. If chlorine is escaping from a cylinder, what would you do?

28. How can chlorine leaks around valve stems be stopped?

29. How can chlorine leaks at the valve discharge outlet be stopped?

30. What properties make chlorine gas so hazardous?

31. What type of breathing apparatus is recommended when repairing chlorine leaks?

32. What first-aid measures should be taken if a person comes in contact with chlorine gas?

33. The UV light intensity that reaches the pathogens in the water is affected by what factors?

34. Routine maintenance of UV disinfection systems includes which tasks?

35. How often should quartz sleeves be cleaned?

36. The service life of UV lamps depends on which factors?

37. How can operators determine the proper way to dispose of used UV lamps?

38. Why is ozone generated on site?

39. The effectiveness of ozone disinfection depends on which factors?

Disinfection
Review Questions

1. Pathogenic organisms are disease-producing organisms
2. Disinfection is the selective destruction or inactivation of pathogenic organisms.
3. The US Environmental Protection Agency establishes drinking water standards.
4. MCL stands for Maximum Contaminant Level.
5. Most disinfectants are more effective in water with a pH around 7.0 than at a pH over 8.0.
6. Relatively cold water requires longer disinfection time or greater quantities of disinfectants.
7. The number and type of organisms present in water influence the effectiveness of disinfection on microorganisms.
8. (1) Ultraviolet rays (2) heat, and (3) ultrasonic waves
9. (1) Iodine (2) bromine (3) bases (sodium hydroxide and lime) (4) ozone
10. The inability of ozone to provide a residual in the distribution system
11. Dose = demand + residual
12. Hydrogen sulfide and ammonia
13. Suspected carcinogenic compounds (trihalomethanes)
14. Chlorine gas lowers the pH; hypochlorite increases the pH
15. The higher the pH the greater the percent of OCl^-
16. The addition of chlorine to water until the chlorine demand has been satisfied and further additions of chlorine result in a free available residual chlorine that is directly proportional to the amount of chlorine added beyond the breakpoint.
17. Prechlorination ahead of any other treatment processes and postchlorination after the water has been treated and before it enters the distribution system
18. When the raw waters contain organic compounds
19. (1) Control of algal and slime growths (2) control of mudball formation (3) improved coagulation (4) reduction of tastes and odors (5) increased chlorine

contact time (6) increased safety factor in disinfection of heavily contaminated water

20. Chemical solution tank for the hypochlorite, diaphragm-type pump, power supply, water pump, pressure switch, and water storage tank
21. (1) Pumping directly into the water (2) pumping through an ejector which draws in additional water for dilution of the hypochlorite solution
22. Plastic containers
23. A week's supply of hypochlorite should be available
24. The fusible is a safety device. The fusible metal softens or melts at 158-165^{o}F to prevent buildup of excessive pressures and the possibility of rupture due to fire or high surrounding temperatures.
25. The upper valve discharges chlorine gas, and the lower valve discharges liquid chlorine from ton chlorine tanks.
26. In this position, either chlorine gas or liquid chlorine may be removed.
27. Turn the cylinder so that the leak is on top and the chlorine will escape as a gas.
28. By closing the valve or tightening the packing gland nut. Tighten the nut or stem by turning it clockwise.
29. By replacing the gasket or adapter connection.
30. Chlorine gas is extremely toxic and corrosive in moist atmospheres.
31. A properly fitting self-contained air or oxygen supply type of breathing apparatus, positive/demand breathing equipment, or rebreather kits are used when repairing a chlorine leak
32. First aid measures depend on the severity of the contact. Move the victim away from the gas area, remove the contaminated clothes and keep the victim warm and quiet. Call a doctor and fire department immediately. Keep the patient breathing.
33. The UV light intensity that reaches the pathogens in the water is affected by the condition of the UV lamps and the quality of the water.
34. (1) Checking the UV monitor for significant reduction in lamp output (2) monitoring the process changes in normal flow conditions (3) checking for fouling of the quartz sleeves and the UV intensity monitor probes (4) checking the indicator light display to ensure that all of the UV lamps are energized (5)

monitoring the elapsed time meter, microbiological results, and lamp log sheet (6) checking the quartz sleeves for discoloration

35. Depends on the quality of the water being treated and the treatment chemicals used prior to disinfection
36. Depends on (1) the level of suspended solids in the water to be disinfected and the fecal coliform level to be achieved (2) the frequency of the on/off cycles (3) the operating temperature of the lamp electrodes
37. Contact the appropriate regulatory agency. Do not throw UV bulbs in trash because they contain mercury.
38. It is unstable and decomposes to elemental oxygen in a short time after generation.

Section 5

Pumps & Equipment Maintenance

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PUMPS

California State University: Sacramento

Updated 12-2017

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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

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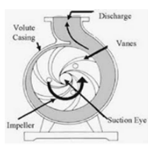
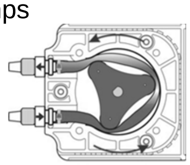
Types of Pumps

- Velocity Pumps



- Positive-Displacement Pumps



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Types of Pumps

- Positive-Displacement Pumps
  - Metering pumps
    - sometimes used to feed chemicals
  - Piston pump
  - Screw pump
- Velocity Pumps
  - Vertical turbine
  - Centrifugal

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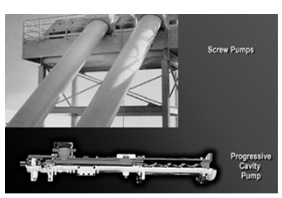
Positive-Displacement Pumps

- Chemical feed pumps
- Delivers a constant volume with each stroke
- Less efficient than centrifugal pumps
- **Cannot operate against a closed discharge valve**
- Types: piston, diaphragm, gear, or screw pump



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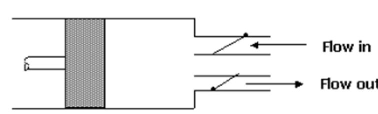
Positive-Displacement Pumps

- Reciprocating (piston) pump - piston moves back and forth in cylinder, liquid enters and leaves through check valves



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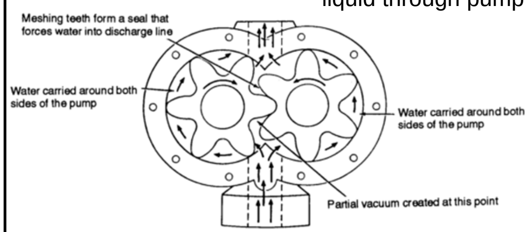
Positive-Displacement Pumps

- Rotary pump - Use lobes or gears to move liquid through pump



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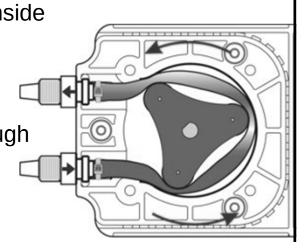
Positive Displacement Pumps

- Peristaltic Pump
  - Fluid to be pumped flows through flexible tube inside a pump casing
  - Rotor inside turns and compresses the tube
  - Rotor forces fluid through tube



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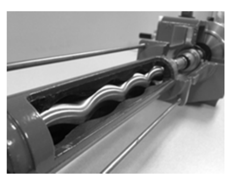
Screw Pumps

Incline screw pumps handle large solids without plugging

- Aka progressive cavity pumps
- Screw pumps are used to lift water to a higher elevation
- This pump consists of a screw operating at a constant speed within a housing or trough
- The screw has a pitch and is set at a specific angle
- When revolving, it carries wastewater up the trough to a discharge point



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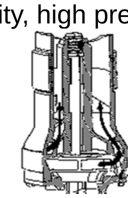
Velocity Pumps

- Spinning impeller or propeller accelerates water to high velocity in pump casing (or volute)
- High velocity, low pressure water is converted to low velocity, high pressure water

Volute



Diffuser

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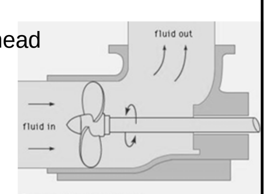
Velocity Pump Design Characteristics

- Axial - flow designs
  - Propeller shaped impeller adds head by lifting action on vanes
  - Water moves parallel to pump instead of being thrown outward
  - High volume, but limited head
  - Not self-priming



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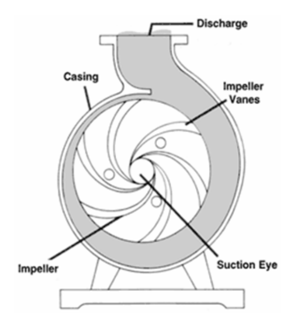
Velocity Pump Design Characteristics

- Radial flow designs
  - Water comes in through center (eye) of impeller
  - Water thrown outward from impeller to diffusers that convert velocity to pressure
  - The discharge is perpendicular to the pump shaft



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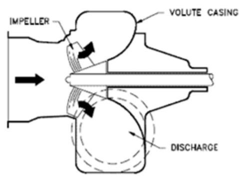
Velocity Pump Design Characteristics

- Mixed - flow designs
  - Has features of axial and radial flow
  - Works well for water with solids



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Centrifugal Pump

- Basically a very simple device: an impeller rotating in a casing
- The impeller is supported on a shaft, which in turn, is supported by bearings
- Liquid coming in at the center (eye) of the impeller is picked up by the vanes and by the rotation of the impeller and then is thrown out by centrifugal force into the discharge

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Centrifugal Pumps

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

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Advantages of Centrifugal Pumps

- Wide range of capacities
- Uniform flow at a constant speed and head
- Low cost
- Ability to be adapted to various types of drivers
- Moderate to high efficiency
- No need for internal lubrication

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Disadvantages of Centrifugal Pumps

- Efficiency is limited to very narrow ranges of flow and head
- Flow capacity greatly depends on discharge pressure
- Generally no self-priming ability
- Can run backwards if check valve fails and sticks open
- Potential impeller damage if pumping abrasive water

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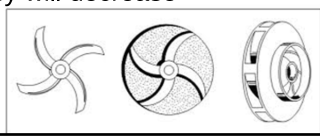
Let's Build a Centrifugal Pump

- First we need a device to spin liquid at high speeds – an impeller
  - As the impeller spins, liquid between the blades is impelled outward by centrifugal force
  - As liquid in the impeller moves outward, it will suck more liquid behind it through this eye

#1: If there is any danger that foreign material may be sucked into the pump, clogging or wearing of the impeller unduly, provide the intake end of the suction piping with a suitable screen

Impeller

- Bronze or stainless steel
- Closed; some single-suction have semi-open; open designs
- Inspect regularly
- As the impeller wears on a pump, the pump efficiency will decrease



Let's Build a Centrifugal Pump

- Now we need a shaft to support and turn the impeller
  - It must maintain the impeller in precisely the right place
  - But that ruggedness does not protect the shaft from the corrosive or abrasive effects of the liquid pumped, so we must protect it with sleeves slid on from either end

#2: Never pump a liquid for which the pump was not designed

Shaft and Sleeves

- Shaft
  - Connects impeller to pump; steel or stainless steel
  - Should be repaired/replaced if grooves or scores appear on the shaft
- Shaft Sleeves
  - Protect shaft from wear from packing rings
  - Generally they are bronze, but various other alloys, ceramics, glass or even rubber-coating are sometimes required.

Let's Build a Centrifugal Pump

- We mount the shaft on sleeve, ball or roller bearings
  - If bearings supporting the turning shaft and impeller are allowed to wear excessively and lower the turning units within a pump's closely fitted mechanism, the life and efficiency of that pump will be seriously threatened.

#3: Keep the right amount of the right lubricant in bearings at all times.

Bearings

- Anti-friction devices for supporting and guiding pump and motor shafts
- Get noisy as they wear out
- If pump bearings are over lubricated, the bearings will overheat and can be damaged or fail
  - Tiny indentations high on the shoulder of a bearing or race is called brinelling
  - When greasing a bearing on an electric motor, the relief plug should be removed and replaced after the motor has run for a few minutes. This prevents you from damaging the seals of the bearing.
- Types: ball, roller, sleeve

Let's Build a Centrifugal Pump

- To connect with the motor, we add a coupling flange
  - Our pump is driven by a separate motor, and we attach a flange to one end of the shaft through which bolts will connect with the motor flange
  - If shafts are met at an angle, every rotation throws tremendous extra load on bearings of both pump and the motor

#4: See that pump and motor flanges are parallel and vertical and that they stay that way.

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Couplings

- Connect pump and motor shafts
- Lubricated require greasing at 6 month intervals
- Dry has rubber or elastomeric membrane
- Calipers and thickness gauges can be used to check alignment on flexible couplings

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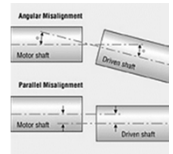
Misalignment of Pump & Motor



- Excessive bearing loading
- Shaft bending
- Premature bearing failure
- Shaft damage
- Checking alignment should be a regular procedure in pump maintenance.
  - Foundations can settle unevenly
  - Piping can change pump position
  - Bolts can loosen
  - Misalignment is a major cause of pump and coupling wear.

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Common Pump & Motor Connections

- Direct coupling
- Angle drive
- Belt or chain
- Flexible coupling
- Close-coupled

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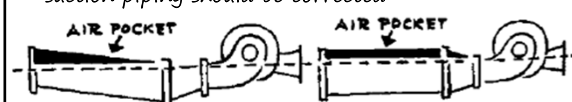
Let's Build a Centrifugal Pump

- Now we need a "straw" through which liquid can be sucked
  - The horizontal pipe slopes upward toward the pump so that air pockets won't be drawn into the pump and cause loss of suction

#5: Any down-sloping toward the pump in suction piping should be corrected



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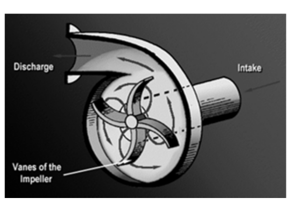
Let's Build a Centrifugal Pump

- We contain and direct the spinning liquid with a casing
  - Designed to minimize friction loss as water is thrown outward from impeller
  - Usually made of cast iron, spiral shape



#6: See that piping puts absolutely no strain on the pump casing.

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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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Let's Build a Centrifugal Pump

- Now our pump is almost complete, but it would leak like a sieve
  - As water is drawn into the spinning impeller, centrifugal force causes it to flow outward, building up high pressure at the outside of the pump (which will force water out) and creating low pressure at the center of the pump (which will draw water in)
    - Water tends to be drawn back from pressure to suction through the space between the impeller and casing – this needs to be plugged

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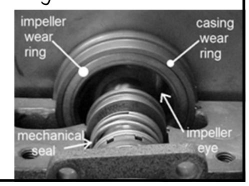
Let's Build a Centrifugal Pump

- So we add wear rings to plug internal liquid leakage
  - Wear rings fill the gaps without having to move the parts of the pump closer together

#7: Never allow a pump to run dry. Water is a lubricant between the rings and impeller.



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Wear Rings

- Restrict flow between impeller discharge and suction
- Leakage reduces pump efficiency
- Installed to protect the impeller and pump casing from excessive wear
- Provides a replaceable wearing surface
- Inspect regularly

#8: Examine wearing rings at regular intervals. When seriously worn, their replacement with greatly improve pump efficiency.

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Let's Build a Centrifugal Pump

- To keep air from being drawn in, we use stuffing boxes
  - We have two good reasons for wanting to keep air out of our pump
    - We want to pump water, not air
    - Air leakage is apt to cause our pump to lose suction
  - Each stuffing box we use consists of a casing, rings of packing and a gland at the outside end
    - A mechanical seal may be used instead

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Stuffing Box

#9 – Packing should be replace periodically. Forcing in a ring or two of new packing instead of replacing worn packing is bad practice. It is apt to dislodge the seal cage.

#10 - Never tighten a gland more than necessary as excessive pressure will wear shaft sleeves unduly.

#11 – If shaft sleeves are badly scored, replace them immediately.

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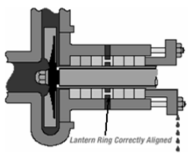
Let's Build a Centrifugal Pump

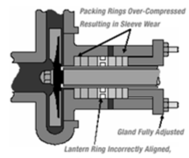
- To make packing more airtight, we add water seal piping
  - In the center of each stuffing box is a "seal cage"
  - This liquid acts both to block out air intake and to lubricate the packing
  - To control liquid flow, draw up the packing gland just tight enough to allow approximately one drop/second flow from the box

#12 – If the liquid being pumped contains grit, a separate source of sealing liquid should be obtained.

Lantern Rings

- Perforated ring placed in stuffing box
- A spacer ring in the packing gland that forms seal around shaft, helps keep air from entering the pump and lubricates packing





Packing Rings

- Asbestos or metal ring lubricated with Teflon or graphite
- Provides a seal where the shaft passes through the pump casing in order to keep air form being drawn or sucked into the pump and/or the water being pumped from coming out

Packing Rings

- 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 slowly, over a period of **several hours** to just enough to allow an occasional drop of liquid (**20-60 drops per minute** is desired)
  - Leakage acts as a lubricant
- Stagger joints 180º if only 2 rings are in stuffing box, space at 120º for 3 rings or **90º if 4 rings or more are in set**

Packing Rings

- If packing is not maintained properly, the following troubles can arise:
  - **Loss of suction** due to air being allowed to enter pump
  - **Shaft or shaft sleeve damage**
  - Water or wastewater **contaminating bearings**
  - **Flooding** of pump station
  - Rust corrosion and unsightliness of pump and area

Mechanical Seals

- Located in stuffing box
- Prevents water from leaking along shaft; keeps air out of pump
- **Should not leak**
- Consists of a rotating ring and stationary element
- The operating temperature on a mechanical seal should never exceed 160ºF (71ºC)
- Mechanical seals are always flushed in some manner to lubricate the seal faces and minimize wear
  - The flushing water pressure in a water-lubricated wastewater pump should be **3-5 psi higher** than the pump discharge pressure.

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
  - Should not leak any water

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Packing vs. Mechanical Seals

- If a pump has packing, water should drip slowly
- If it has a mechanical seal, no leakage should occur

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Packing Rings vs. Mechanical Seal

- Advantages
  - Less expensive, short term
  - Can accommodate some looseness
- Disadvantages
  - Increased wear on shaft or shaft sleeve
  - Increased labor required for adjustment and replacement

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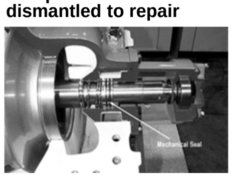
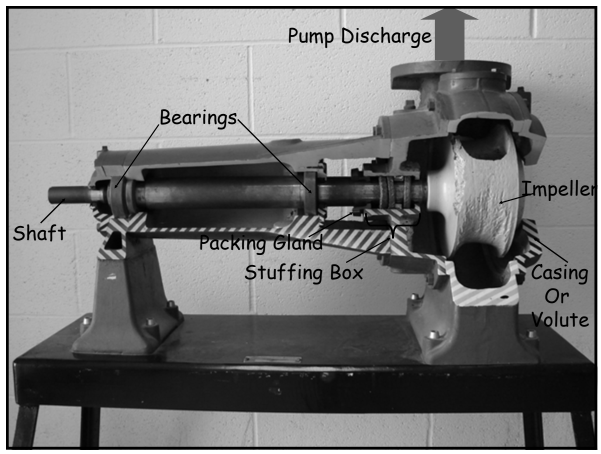
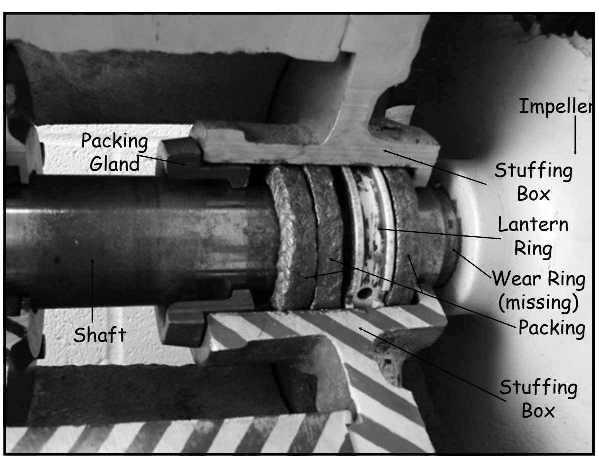
Mechanical Seal vs. Packing Rings

- Advantages
  - **Last 3-4 years**, which can be a savings in labor
  - Usually there is **no damage to shaft sleeve**
  - **Continual adjusting, cleaning or repacking is not required**
  - Possibility of flooding lift station because a pump has thrown its packing is eliminated; however mechanical seals can fail and lift stations can be flooded
- Disadvantages
  - **High initial cost**
  - **Great skill and care needed to replace**
  - When they fail, the pump must be shut down
  - **Pump must be dismantled to repair**







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Centrifugal Pump Operation

- Pump Starting -
  - Impeller must be submerged for a pump to start
    - Should never be run empty, except momentarily, because parts lubricated by water would be damaged
  - Foot valve helps hold prime
  - Discharge valve should open slowly to control water hammer
  - In small pumps, a check valve closes immediately when pump stops to prevent flow reversal
  - In large pumps, discharge valve may close before pump stops

Centrifugal Pump Operation

- Pump shut down for extended period of time -
  - Close the valve in the suction line
  - Close the valve in the discharge line
  - Drain the pump casing

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
  - Variable speed pumping equipment can be adjusted to match the inflow rate

Monitoring Operational Variables

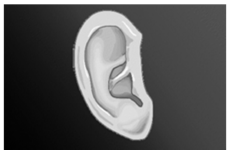
- Pump and motor should be tested and complete test results recorded as a baseline for the measurement of performance within the first 30 days of operation

Monitoring Operational Variables

- Suction and Discharge Heads
  - Pressure gauges
- Bearing and Motor Temperature
  - Temp indicators can shut down pump if temp gets too high
  - Check temp of motor by feel

Monitoring Operational Variables

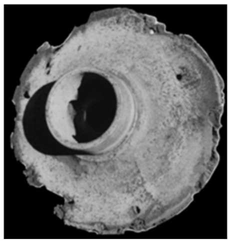
- Vibration
  - Detectors can sense malfunctions causing excess vibration
  - Operators can learn to distinguish between normal and abnormal sounds



Monitoring Operational Variables

- Likely causes of vibration
  - Bad bearings or bearing failure
  - Imbalance of rotating elements, damage to impeller
  - Misalignment from shifts in underlying foundation
  - Improper motor to pump alignment

Monitoring Operational Variables

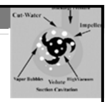


- Speed
  - Cavitation can occur at low and high speeds
  - Creation of vapor bubbles due to partial vacuum created by incomplete filling of the pump

Monitoring Operational Variables

- Cavitation is a noise coming from a centrifugal pump that sounds like marbles trapped in the volute
- A condition where small bubbles of vapor form and explode against the impeller, causing a pinging sound
- Best method to prevent it from occurring is to reduce the suction lift

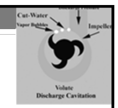
Suction Cavitation



- Suction Cavitation occurs when the pump suction is under a low pressure/high vacuum condition where the liquid turns into a vapor at the eye of the pump impeller.
- This vapor is carried over to the discharge side of the pump where it no longer sees vacuum and is compressed back into a liquid by the discharge pressure.
- This imploding action occurs violently and attacks the face of the impeller.
- An impeller that has been operating under a suction cavitation condition has large chunks of material removed from its face causing premature failure of the pump.

Information from http://www.pumpworld.com/Cavitation_discharge.htm

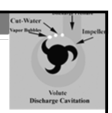
Discharge Cavitation



- Discharge Cavitation occurs when the pump discharge is extremely high.
- It normally occurs in a pump that is running at less than 10% of its best efficiency point.
- The high discharge pressure causes the majority of the fluid to circulate inside the pump instead of being allowed to flow out the discharge.
- As the liquid flows around the impeller it must pass through the small clearance between the impeller and the pump cutwater at extremely high velocity.

Information from http://www.pumpworld.com/Cavitation_discharge.htm

Discharge Cavitation



- This velocity causes a vacuum to develop at the cutwater similar to what occurs in a venturi and turns the liquid into a vapor.
- A pump that has been operating under these conditions shows premature wear of the impeller vane tips and the pump cutwater.
- In addition due to the high pressure condition premature failure of the pump mechanical seal and bearings can be expected and under extreme conditions will break the impeller shaft.

Information from http://www.pumpworld.com/Cavitation_discharge.htm

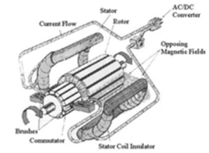
Inspection and Maintenance

- Inspection and maintenance prolongs life of pumps
  - Checking operating temperature of bearings
  - Checking packing glands
  - Operating two or more pumps of the same size alternatively to equalize wear
  - Check parallel and angular alignment of the coupling on the pump and motor
    - A feeler gauge, dial indicator calipers are tools that can be used to check proper alignment
- Necessary for warranty
- Keep records of all maintenance on each pump
- Keep log of operating hours

Inspection: Impellers

- Wear on impeller and volute
- Cavitation marks
- Chips, broken tips, corrosion, unusual wear
- Tightness on shaft
- Clearances
- Tears or bubbles (if rubber coated)

Pump Won't Start?



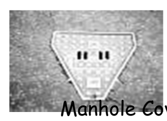
- Incorrect power supply
- No power supply
- Incorrectly connected
- Fuse out, loose or open connection
- Rotating parts of motor jammed mechanically
- Internal circuitry open

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 in place before restarting
- Machinery creating excessive noise shall be equipped with mufflers.

Pump Safety: Wet Wells

- Confined spaces
- Corrosion of ladder rungs
- Explosive atmospheres
- Hydrogen sulfide accumulation
- Slippery surfaces



Manhole Cover, London

Maintenance

California State University, Sacramento

Water Treatment Plant Operations Vol. II

Fleming Training Center | TN Department of Environment & Conservation

System Maintenance

- A good maintenance program is a must in order to maintain successful operation of a water plant
- Should include everything from mechanical equipment to the care of the plant grounds, buildings and structures
- Mechanical maintenance is of prime importance as the equipment must be kept in good operating condition in order for the plant to maintain peak performance

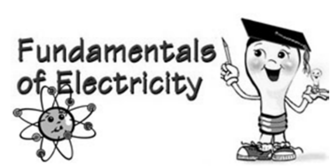
Preventive Maintenance Records

- Preventive maintenance programs keep equipment in good working condition and correct small malfunctions before they turn into big problems
- A good record keeping system tells when maintenance is due and shows equipment performance
- Equipment service cards and service record cards should be filled out for each piece of equipment in the plant

Electrical Equipment

Beware of Electricity

- Do not attempt to install, troubleshoot, maintain, repair, or replace electrical equipment, panels, controls, wiring, or circuits unless
  - You know what you are doing
  - You are qualified
  - You are authorized



Volts

- Also known as electromotive force (EMF)
- The electrical pressure available to cause a flow of current (amperage) when a circuit is closed
- Voltage (E) is the force that is necessary to push electricity or electric current through a wire
- Two types:
  - Direct current (DC)
  - Alternating current (AC)

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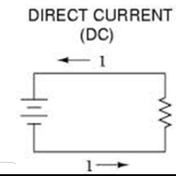
Direct Current (DC)

- Flow in one direction and is essentially free from pulsation
- Used exclusively in automotive equipment, certain types of welding equipment, and a variety of portable equipment
- Found in various voltages
  - 6, 12, 24, 48, and 110 volts
- All batteries are DC



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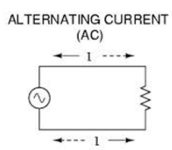
Alternating Current (AC)

- Voltage and current periodically change direction and amplitude
- Current goes from zero to maximum strength, back to zero, and to the same strength in the opposite direction
- Hertz describes the frequency of cycles completed per second
- Classified as
  - Single phase
  - Two phase
  - Three phase or polyphase



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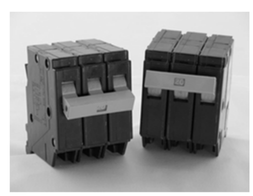
Alternating Current – Circuit Breakers

- Used to protect electric circuits from overloads
- Metal conductors that de-energize the main circuit is overheated by too much current passing through



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Amps

- The measurement of current or electron flow and is an indication of work being done or "how hard the electricity is working"
- The practical unit of electrical current

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Watts (W) and Kilowatts(kW)

- The units of measurement of the rate at which power is being used or generated
- In DC circuits, watts equal the voltage times the current

  Watts = (volts)(amps)
- In AC polyphase circuits, you have to include the power factor and the √3

  Watts = (volts)(amps)(power factor)(1.73)
- Power factor is the ratio of actual power passing through a circuit to the apparent power
  - Usually somewhere near 0.9

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Tools, Meters and Testers

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Voltage Testing

- Multimeter used for checking voltage
- Use meter that has sufficient range to measure voltage you would expect to find
- Tells if AC or DC and intensity or voltage
- Used to test for open circuits, blown fuses, single phasing of motors, grounds, etc.

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Ammeter

- Records the current or "amps" flowing in the circuit
- Two common types:
  - Clamp-on type – used for testing
    - Clamped around a wire supplying a motor
  - In-line type – installed in a panel or piece of equipment
    - Connected in line with the power lead or leads

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Megger

- Used for checking the insulation resistance on motors, feeders, bus bar systems, grounds, and branch circuit wiring
- Connected to a motor terminal at the starter
- Test results show if the insulation is deteriorating or cut
- Three types
  - Crank operated
  - Battery operated
  - Instrument

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Ohmmeters

- Used to measure the resistance in a circuit
- Also called circuit testers
- Electrical circuit must be OFF to use ohmmeter
- Ohmmeter supplies own power

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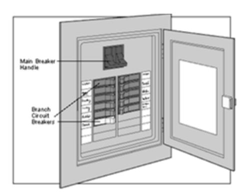

Equipment Protective Devices

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Fuses

- A protective device having a strip or wire of fusible metal that will melt and break the electrical circuit when subjected to excessive temperature
- Common types:
  - Current-limiting fuses – used to protect power distribution circuits
  - Dual-element fuses – used for motor protection circuits
- Be sure to replace fuses with proper size and type indicated for that circuit

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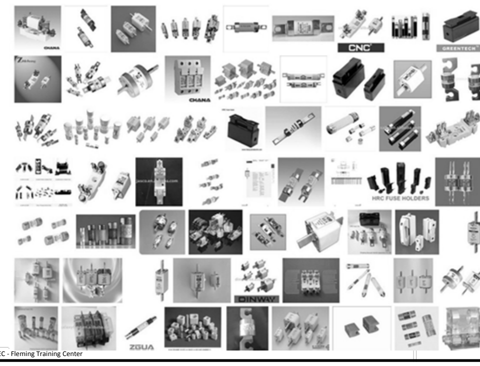
Fuses



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Circuit Breakers

- A protective device consisting of a switch that opens automatically when the current of the voltage exceeds or falls below a certain limit
- Can be reset unlike a fuse
- Can be visually inspected to find out if it has been tripped

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Auxiliary Electrical Power

- Standby power generation – three types
  - Engine driven generator
  - Batteries
  - Alternate power source
- Emergency lighting
- Batteries

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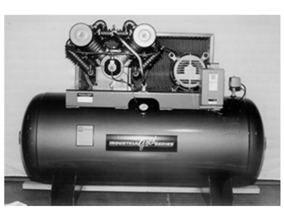
Compressors

- A device used to increase the pressure of air or gas
- Consists of a suction pipe with a filter and a discharge pipe that connects to an air receiver



- Can be simple diaphragm type or complex rotary, piston, or sliding vane type

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Compressor Maintenance

- Inspect the suction filter of the compressor monthly
  - Clean or replace filter every 3-6 months
- Lubrication must be inspected daily
  - Oil should be replaced every 3 months
- Cylinder or casing fins should be cleaned weekly
- Inspect unloader
  - If not working properly, compressor will not start, stall, or burn off belts if belt driven
- Test the safety valves weekly

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Compressor Maintenance

- Drain the condensate from air receiver daily
  - If has automatic drain, inspect periodically
- Inspect belt tension on compressor
  - Should be able to press the belt down, in the center, with your hand approximately ¾ inch
- Examine operating controls
  - Make sure compressor is starting and stopping at the proper settings
- Ensure portable compressors have oil in tool oiler reservoir
- Clean thoroughly each month

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Valves

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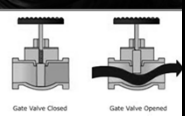
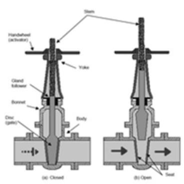
Gate Valves



- Basic parts: operator (handle), shaft packing assembly, bonnet, valve body with seats, stem, and disc
- Valve disc is raised/lowered by a threaded shaft
- Disc is screwed down until it wedges itself between two machined valve seats
- Not used to control flows
- Either rising stem or non-rising stem type



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Gate Valves – O & M

- 1. Open valve fully
- 2. Operate all large valves at least yearly to ensure proper operation
- 3. Inspect valve stem packing for leaks
- 4. If the valve has a rising stem, keep stem threads clean and lubricated
- 5. Close valves slowly in pressure lines to prevent water hammer
- 6. If a valve will not close by using the handwheel, check for the cause; Using a "cheater" bar will only aggravate the problem

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Gate Valves - Maintenance

Frequency	Service
Annually	**Replace packing:** Remove all old packing from stuffing box. Insert new split ring packing while staggering the ring splits.
Semi-annually	**Operate valve:** Operate inactive gate valves to prevent sticking
Annually	**Lubricate gearing:** Lubricate gate valves as recommended by manufacturer
Semi-annually	**Lubricate rising stem threads:** Clean threads on rising stem gate valves and lubricate with grease
Annually	**Reface leaky gate valve seats:** Remove bonnet and clean examine disc body thoroughly. Check and service all parts of valve completely. Remove all old packing a clean out stiffing box. Do not salvage old gasket. After cleaning and examining all parts, determine whether valve can be repaired or must be replaced. Test repaired valve before putting back in line.

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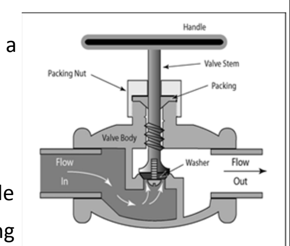
Globe Valves

- Use a circular disc to make a flat surface contact with a ground-fitted valve seat
- Internal design enables valve to be used in a controlling /throttling mode
- Can be of rising or nonrising stem type
- O & M similar to gate valve



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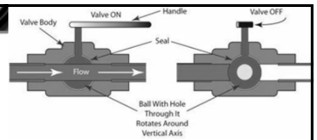
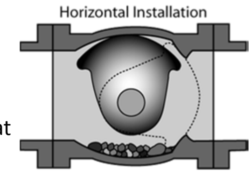
Ball Valves



- A valve consisting of a ball resting in a cylindrical seat
- A hole is bored through the ball to allow water to flow when the valve is open
- When the valve is rotated 90°, the valve is closed
- Should be operated fully open or fully closed
  - Throttling can lead to damage to the seal

Eccentric Valves



- Uses a cam shaped plug to match an eccentric valve seat
- As the valve is closed, the plug throttles the flow yet maintains a smooth flow rate
- Excellent for controlling the flows of slurries and sludges

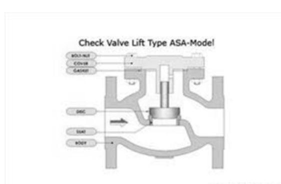
Butterfly Valves

- Used primarily as a control valve
- Uses a machined disc that can be opened to 90º to allow full flow through valve
- Closed valve is forced against the continuous rubber seat

Check Valves

- Allows water to flow in only one direction
- Three types:
  - Swing check – a movable disc (clapper) rests at a right angle to the flow an seats against a ground seat
  - Wafer check – a circular disc that hinges in the center of the disc. Flow collapses the disc and flow stoppage allows the disc to return to its circular form
  - Lift check – uses a vertical lift disc or ball. Flow lifts the disc/ball and allows water to flow through.
    - Foot valves are nearly always vertical lift valves

Lift Check Valve



Swing Check Valve

Wafer Check Valve

Check Valves - Maintenance

Frequency	Service
Annually	**Inspect disc facing**: Open valves to observe condition of facing on swing check valves
Annually	**Check pin wear:** Check pin wear on balanced check valve, since disc must be accurately positioned in seat to prevent leakage

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^{o}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 Vocabulary

1. Axial-Flow Pump – a pump in which a propeller-like impeller forces water out in the direction parallel to the shaft. Also called a propeller pump.
2. Bearing – anti-friction device used to support and guide a pump and motor shafts.
3. Casing – the enclosure surrounding a pump impeller, into which the suction and discharge ports are machined.
4. Cavitation – a condition that can occur when pumps are run too fast or water is forced to change direction quickly. A partial vacuum forms near the pipe wall or impeller blade causing potentially rapid pitting of the metal.
5. Centrifugal Pumps – a pump consisting of an impeller on a rotating shaft enclosed by a casing having suction and discharge connections. The spinning impeller throws water outward at high velocity, and the casing shape converts this velocity to pressure.
6. Closed-Coupled Pump – a pump assembly where the impeller is mounted on the shaft of the motor that drives the pump.
7. Diffuser Vanes – vanes installed within a pump casing on diffuser centrifugal pumps to change velocity head to pressure head.
8. Double-Suction Pump – a centrifugal pump in which the water enters from both sides of the impeller. Also called a split-case pump.
9. Foot Valve – a check valve placed in the bottom of the suction pipe of a pump, which opens to allow water to enter the suction pipe but closes to prevent water from passing out of it at the bottom end. Keeps prime.
10. Frame-Mounted Pump – a centrifugal pump in which the pump shaft is connected to the motor shaft with a coupling.
11. Impeller – the rotating set of vanes that forces water through the pump.
12. Jet Pump – a device that pumps fluid by converting the energy of a high-pressure fluid into that of a high-velocity fluid.
13. Lantern Ring – a perforated ring placed around the pump shaft in the stuffing box. Water from the pump discharge is piped to this ring. The water forms a liquid seal around the shaft and lubricates the packing.
14. Mechanical Seal – a seal placed on the pump shaft to prevent water from leaking from the pump along the shaft; the seal also prevents air from entering the pump.
15. Mixed-Flow Pump – a pump that imparts both radial and axial flow to the water.
16. Packing – rings of graphite-impregnated cotton, flax, or synthetic materials, used to control leakage along a valve stem or a pump shaft.
17. Packing Gland – a follower ring that compressed the packing in the stuffing box.
18. Positive Displacement Pump – a pump that delivers a precise volume of liquid for each stroke of the piston or rotation of the shaft.
19. Prime Mover – a source of power, such as an internal combustion engine or an electric motor, designed to supply force and motion to drive machinery, such as a pump.

20. Radial-Flow Pump – a pump that moves water by centrifugal force, spinning the water radially outward from the center of the impeller.
21. Reciprocating Pump – a type of positive-displacement pump consisting of a closed cylinder containing a piston or plunger to draw liquid into the cylinder through an inlet valve and forces it out through an outlet valve.
22. Rotary Pump – a type of positive-displacement pump consisting of elements resembling gears that rotate in a close-fitting pump case. The rotation of these elements alternately draws in and discharges the water being pumped.
23. Single-Suction Pump – a centrifugal pump in which the water enters from only one side of the impeller. Also called an end-suction pump.
24. Stuffing Box – a portion of the pump casing through which the shaft extends and in which packing or a mechanical seal is placed to prevent leakage.
25. Submersible Pump – a vertical-turbine pump with the motor placed below the impellers. The motor is designed to be submersed in water.
26. Suction Lift – the condition existing when the source of water supply is below the centerline of the pump.
27. Velocity Pump – the general class of pumps that use a rapidly turning impeller to impart kinetic energy or velocity to fluids. The pump casing then converts this velocity head, in part, to pressure head. Also known as kinetic pumps.
28. Vertical Turbine Pump – a centrifugal pump, commonly of the multistage, diffuser type, in which the pump shaft is mounted vertically.
29. Volute – the expanding section of pump casing (in a volute centrifugal pump), which converts velocity head to pressure head..
30. Water Hammer – the potentially damaging slam that occurs in a pipe when a sudden change in water velocity (usually as a result of too-rapidly starting a pump or operating a valve) creates a great increase in water pressure.
31. Wear Rings – rings made of brass or bronze placed on the impeller and/or casing of a centrifugal pump to control the amount of water that is allowed to leak from the discharge to the suction side of the pump.

Pump and Motor Review Questions

1. Leakage of water around the packing on a centrifugal pump is important because it acts as a (n):
   a. Adhesive
   b. Lubricant
   c. Absorbent
   d. Backflow preventer

2. What is the purpose of wear rings in a pump?
   a. Hold the shaft in place
   b. Hold the impeller in place
   c. Control amount of water leaking from discharge to suction side
   d. Prevent oil from getting into the casing of the pump

3. Which of the following does a lantern ring accomplish?
   a. Lubricates the packing
   b. Helps keep air from entering the pump
   c. Both (a.) and (b.)

4. Closed, open and semi-open are types of what pump part?
   a. Impeller
   b. Shaft sleeve
   c. Casing
   d. Coupling

5. When tightening the packing on a centrifugal pump, which of the following applies?
   a. Tighten hand tight, never use a wrench
   b. Tighten to 20 foot pounds of pressure
   c. Tighten slowly, over a period of several hours
   d. Tighten until no leakage can be seen from the shaft

6. Excessive vibrations in a pump can be caused by:
   a. Bearing failure
   b. Damage to the impeller
   c. Misalignment of the pump shaft and motor
   d. All of the above

7. What component can be installed on a pump to hold the prime?
   a. Toe valve
   b. Foot valve
   c. Prime valve
   d. Casing valve

8. The operating temperature of a mechanical seal should not exceed:
   a. 60°C
   b. 150°F
   c. 160°F
   d. 71°C
   e. c and d

9. What is the term for the condition where small bubbles of vapor form and explode against the impeller, causing a pinging sound?
   a. Corrosion
   b. Cavitation
   c. Aeration
   d. Combustion

10. The first thing that should be done before any work is begun on a pump or electrical motor is:
    a. Notify the state
    b. Put on safety goggles
    c. Lock out the power source and tag it
    d. Have a competent person to supervise the work

11. Under what operating condition do electric motors pull the most current?
    a. At start up
    b. At full operating speed
    c. At shut down
    d. When locked out

12. Positive displacement pumps are rarely used for water distribution because:
    a. They require too much maintenance
    b. They are no longer manufactured
    c. They require constant observation
    d. Centrifugal pumps are much more efficient

13. Another name for double-suction pump is
    a. Double-jet pump
    b. Reciprocating pump
    c. Horizontal split-case pump
    d. Double-displacement pump

14. As the impeller on a pump becomes worn, the pump efficiency will:
    a. Decrease
    b. Increase
    c. Stay the same

15. How do the two basic parts of a velocity pump operate?

16. What are two designs used to change high velocity to high pressure in a pump?

17. In what type of pump are centrifugal force and the lifting action of the impeller vanes combined to develop the total dynamic head?

18. Identify one unique safety advantage that velocity pumps have over positive-displacement pumps.

19. What is the multistage centrifugal pump? What effects does the design have on discharge pressure and flow volume?

20. What are two types of vertical turbine pump, as distinguished by pump and motor arrangement, which are commonly used to pump ground water from wells?

21. What type of vertical turbine pump is commonly used as an inline booster pump?

22. Describe the two main parts of a jet pump.

23. What is the most common used of positive-displacement pumps in water plants today?

24. What is the purpose of the foot valve on a centrifugal pump?

25. How is the casing of a double-suction pump disassembled?

26. What is the function of wear rings in centrifugal pumps of the closed-impeller design? What is the function of the lantern rings?

27. Describe the two common types of seals used to control leakage between the pump shaft and the casing.

28. What feature distinguishes a close-coupled pump and motor?

29. What is the value of listening to a pump or laying a hand on the unit as it operates?

30. Define the term "racking" as applied to pump and motor control.

31. When do most electric motors take the most current?

32. What are three major ways of reducing power costs where electric motors are used?

33. What effect could over lubrication of motor bearings have?

34. Why should emery cloth not be used around electrical machines?

35. What are the most likely causes of vibration in an existing pump installation?

36. What can happen when a fuse blows on a single leg of a three-phase circuit?

37. Name at least three common fuels for internal-combustion engines.

38. List the type of information that should be recorded on a basic data card for pumping equipment.

39. What is the first rule of safety when repairing electrical devices?

Answers:

1.	B	6.	D	11.	A
2.	C	7.	B	12.	D
3.	C	8.	E	13.	C
4.	A	9.	B	14.	A
5.	C	10.	C		

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 6

Cross Connection Control

Cross-Connection Control

Outline

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

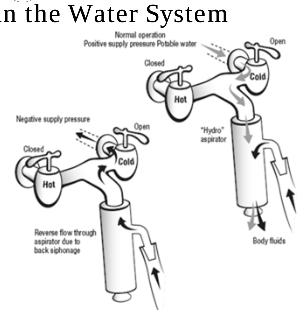
Backflow Case Study

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



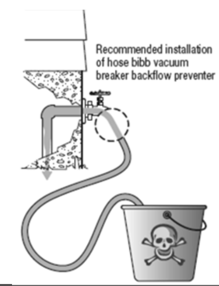
Backflow Case Study

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



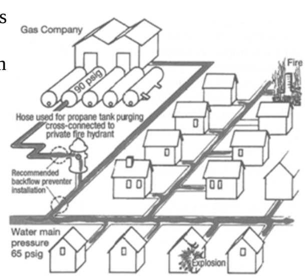
Backflow Case Study

Propane Gas in the Water Mains

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

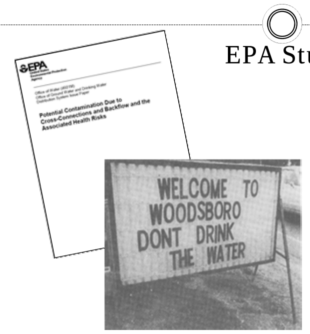
Vapor pressure of propane residual in the tank exceeded water main pressure

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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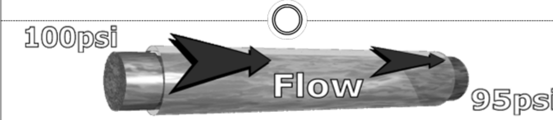
Hydraulics and Pressure



- 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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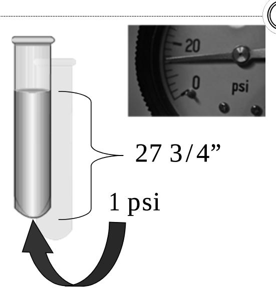
Head Pressure



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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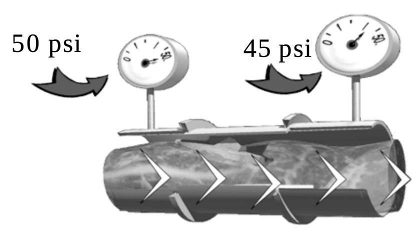
Normal Flow



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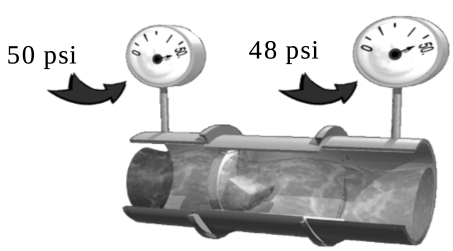
No Flow



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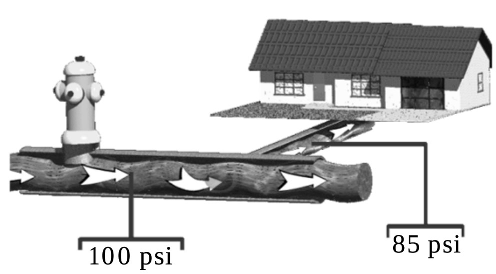
Normal Flow



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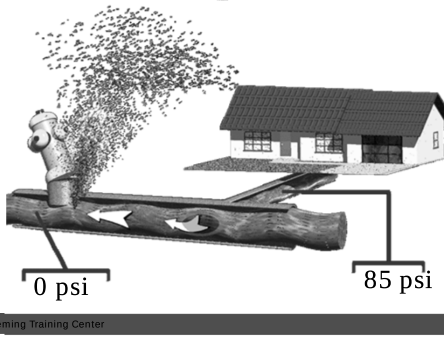
Reverse Flow - Backflow



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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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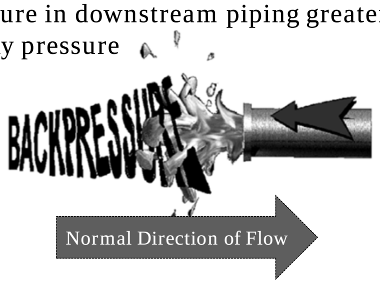
Backpressure

- Pressure in downstream piping greater than supply pressure



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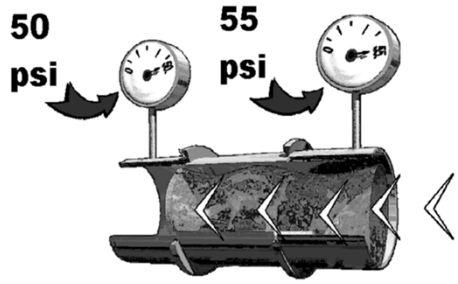
Backpressure



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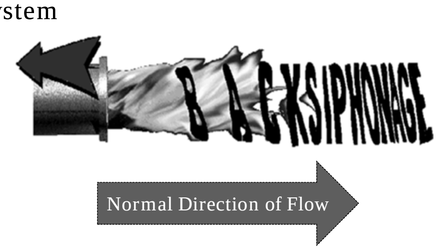
Backsiphonage

- 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…

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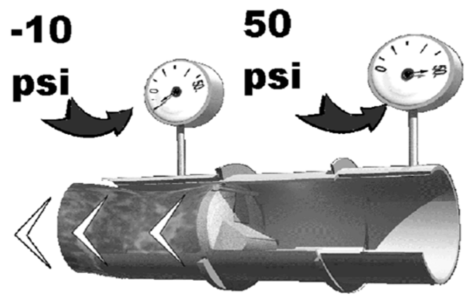
Backsiphonage



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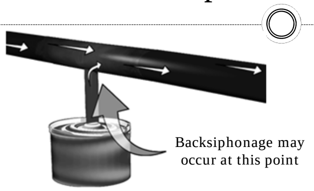
Aspirator Effect



- 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

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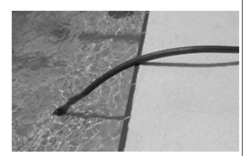
Cross-Connection

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



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Direct Cross-Connection

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

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Indirect Cross-Connection

- An indirect cross-connection is subject to backsiphonage only

Submerged Inlet

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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

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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

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Approved Air Gap Separation

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

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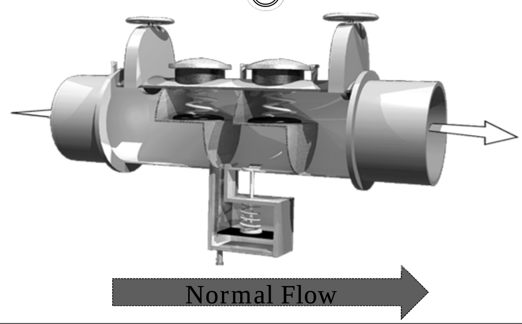
Reduced Pressure Principle Assembly



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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

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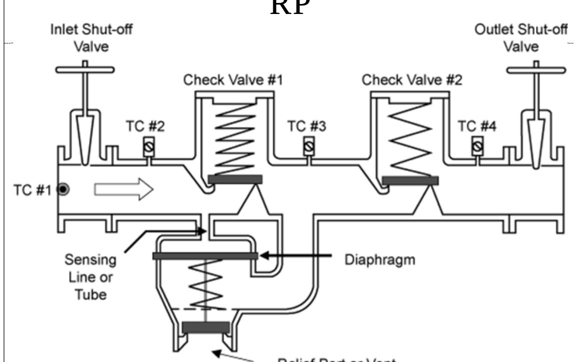
RP



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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

<u>Backflow Protection Against</u>:

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

BEST DEVICE FOR PROTECTION

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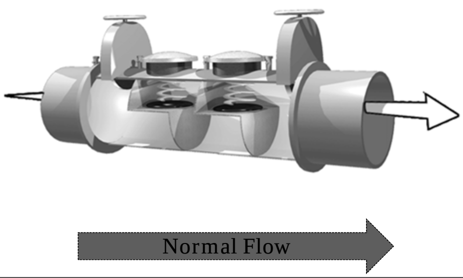
Double Check Valve Assembly (DC)



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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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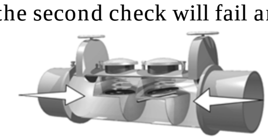
Double Check Valve Assembly (DC)

- 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)

<u>Backflow Protection Against</u>:

- Backsiphonage
- Backpressure
- Pollutant <u>only</u>

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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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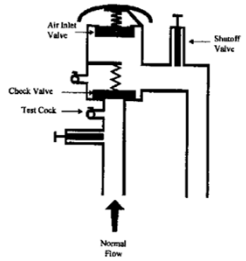
Pressure Vacuum Breaker (PVB)



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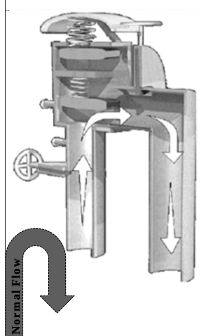
Pressure Vacuum Breaker (PVB)



- 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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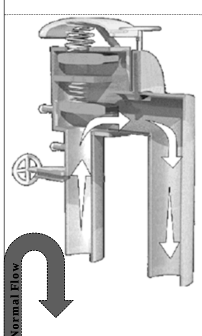
Pressure Vacuum Breaker (PVB)



- 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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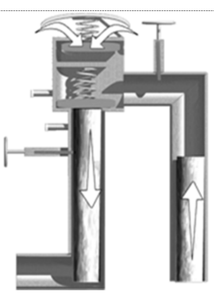
PVB Backsiphonage Condition



- 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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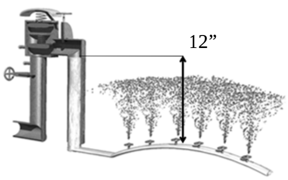
Installation of PVB

- 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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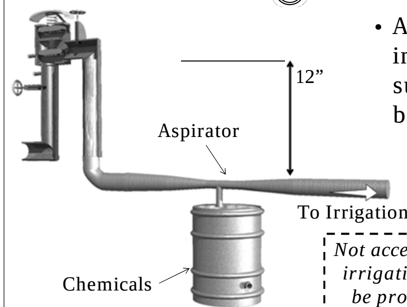
Pressure Vacuum Breaker



- Acceptable installation not subject to backpressure

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

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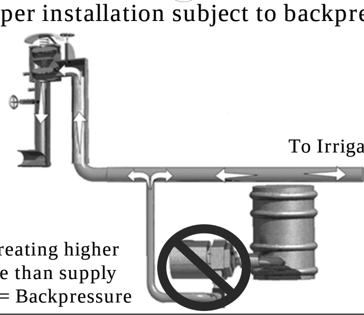
Pressure Vacuum Breaker

- Improper installation subject to backpressure



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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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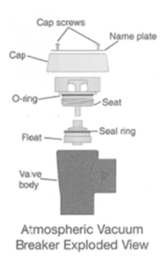
Atmospheric Vacuum Breaker (AVB)



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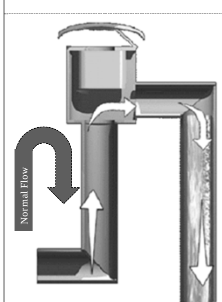
Atmospheric Vacuum Breaker (AVB)



- 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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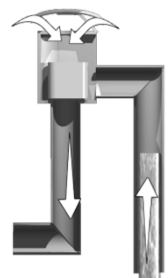
Atmospheric Vacuum Breaker (AVB)

- 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



Loss of supply pressure

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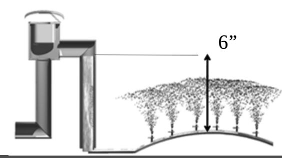
Installation of AVB

- 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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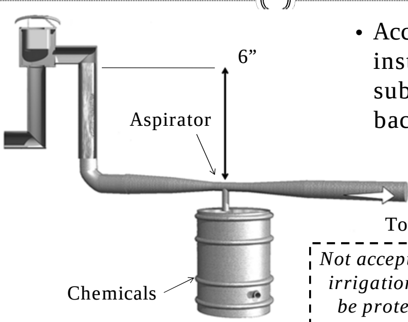
Atmospheric Vacuum Breaker



- Acceptable installation not subject to backpressure

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

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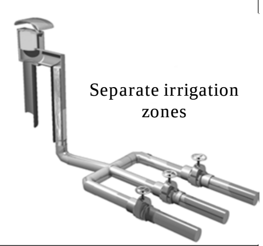
Atmospheric Vacuum Breaker

- 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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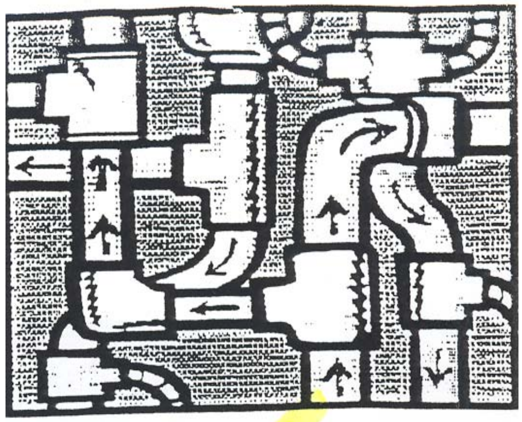

Vocabulary

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 7

Safety

SAFETY

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ACCIDENT

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

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GENERAL DUTY CLAUSE

Federal – 29 CFR 1903.1

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

3

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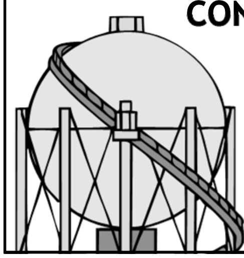

CONFINED SPACES

4

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CONFINED SPACE CONDITIONS

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

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CONFINED SPACE EXAMPLES

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

6

EQUIPMENT NEEDED

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

EQUIPMENT NEEDED cont'd

- PPE
- Ladder
- Rope
- Breathing apparatus

SPACES THAT REQUIRE PERMITS

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

ATMOSPHERIC HAZARDS

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

HYDROGEN SULFIDE - H_2S

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

METHANE GAS - CH_4

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

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CARBON MONOXIDE - CO

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

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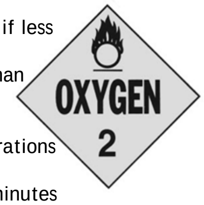
OXYGEN – O_2

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



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OXYGEN – O_2

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

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OXYGEN – O_2

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

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ATMOSPHERIC ALARM UNITS

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

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ATMOSPHERIC ALARM UNITS

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

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REQUIRED TRAINING

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

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RECORD KEEPING

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

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GENERAL REQUIREMENTS

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

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CONFINED SPACE REQUIREMENTS

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

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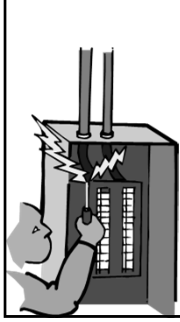

ELECTRICAL SAFETY

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ELECTRICAL SAFETY

OSHA says:

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

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TRANSFORMER

- Allows energy to be transferred in an AC system for one circuit to another
- 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

FIRE PROTECTION

FIRE PROTECTION

Equipment

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

FIRE PROTECTION

Fire Protection Equipment

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

TYPES OF FIRE EXTINGUISHERS

- **Class A**

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

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

TYPES OF FIRE EXTINGUISHERS

- **Class C**

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

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FIRE EXTINGUISHERS

Types of Fire Extinguishers

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

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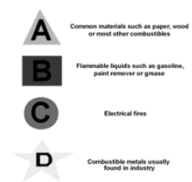
TYPES OF FIRE EXTINGUISHERS

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



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FIRE EXTINGUISHERS

- To operate a fire extinguisher, remember the word **PASS**
  - **P**ull the pin. Hold the extinguisher with the nozzle pointing away from you.
  - **A**im low. Point the extinguisher at the base of the fire.
  - **S**queeze the lever slowly and evenly.
  - **S**weep the nozzle from side-to-side.

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CHEMICAL SAFETY

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PERSONAL PROTECTIVE EQUIPMENT (PPE)

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

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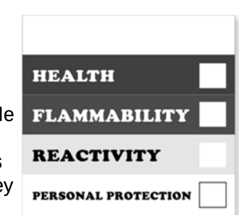
RTK LABELS

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



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NFPA

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

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CHEMICAL HAZARD LABEL

Degrees of Hazard

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

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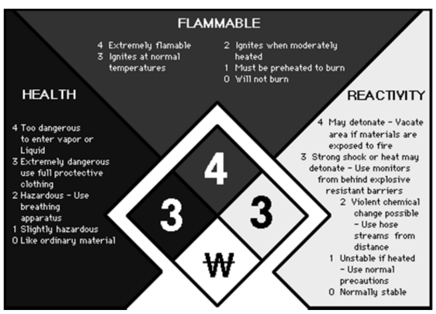
CHEMICAL HAZARD LABEL



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CHEMICAL HAZARD LABEL

Special

- W → water reactive
- Ox → oxidizing agent

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OSHA PICTOGRAMS

Flammables, Oxidizers, Explosives, Acute toxicity, Corrosives

Gases under pressure, Carcinogens, Environmental toxicity, Irritant

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WORKPLACE LABELING

- Can HMIS or NFPA system be used?
- While, the hazard category does not appear on the label, consider

GHS Category	Hazard		HMIS/NFPA Category	Hazard
1	highest		1	slight
2	high		2	moderate
3	medium	→	3	serious
4	low		4	severe

NFPA categories were intended for emergency response, not workplace hazards; only considers acute effects, does not consider chronic effects

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TERMS

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

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CHLORINE & HYPOCHLORITE SAFETY

CHLORINE GAS – Cl_2

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

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CHLORINE GAS – Cl_2

- Inhalation can cause serious lung damage and may be fatal
  - 1000 ppm (0.1%) is likely to be fatal after a few deep breaths
    - half that concentration, fatal after a few minutes
- It takes as little as 3 ppm to be detected as a distinct odor

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CHLORINE SAFETY

Safety Precautions for Chlorine Gas

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

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CHLORINE SAFETY

Where Chlorine Gas Is Used:

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

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CHLORINE SAFETY

Where Chlorine Gas Is Used (cont'd):

- Must have a chlorine gas detection device connected to an alarm that can be heard throughout the treatment plant
- All gaseous feed chlorine installations shall be equipped with appropriate leak repair kits
- A fusible plug, designed to melt at 158º to 165ºF (70-74ºC), is located in the valve on a 150-lb cylinder and on the head of a ton container
  - It is designed to relieve pressure in the cylinder or container when exposed to high heat
- Leak detection – an ammonia solution produces white "smoke" in the presence of chlorine
  - A sensor type leak detector is the best means of detecting small leaks, less than 1ppm

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CHLORINE GAS CONTAINERS

- 3 types of Containers
  - 150 lb cylinder – Emergency repair kit A
  - Ton cylinder – Emergency repair kit B
  - Railroad cars – Emergency repair kit C

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CHLORINE SAFETY

Calcium Hypochlorite (HTH)

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

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CHLORINE SAFETY

Calcium Hypochlorite (HTH)

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

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CHLORINE SAFETY

Calcium Hypochlorite (HTH)

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

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CHLORINE SAFETY

Calcium Hypochlorite (HTH) – PPE

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

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Section 8

Laboratory

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Laboratory Practices

1

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Water Quality

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

2

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Water Quality

Degradation

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

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Water Quality

Analysis

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

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Sampling

Types of Samples

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

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Sampling

Sample Volume and Storage

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

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

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Sampling

Sample Labeling

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

Sampling

Selecting Sampling Points

- Raw-water supply
- Treatment plant
- Distribution system

Sampling

Raw-water Sampling Points

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

Sampling

Treatment Plant Sampling Points

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

Sampling

Distribution Sampling Points

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

Sampling

Distribution Samples

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

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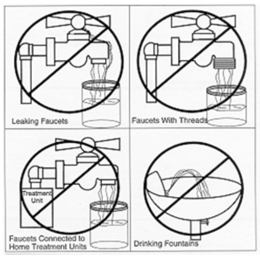
Sampling

Monthly Distribution System Bacteriological Samples

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



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Sampling

Monthly Distribution System Bacteriological Samples

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

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Collection of Samples

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

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Collection of Samples

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

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Collection of Samples

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

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Collection of Samples

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

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Microbiological Indicator Organism

- Always present in contaminated water
- Always absent when no contamination
- Survives longer in water than other pathogens
- Is easily identified
- Water treatment indicator organism

Total Coliforms

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EPA Approved Methods

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

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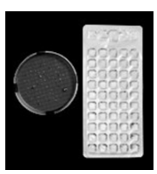
Bacteriological Samples

- The MCL for coliform bacteria is based on presence or absence
- Finished and distributed water should be Zero (absent)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Bacteriological Testing

- Results must keep results for 5 years
- Must collect chlorine residual wherever a bac't sample is collected
- Sample must be tested within 30 hours of sample collection (holding time)
- Sample must be incubated at 35 +/-5°C for 24 hours
- Any sample that test positive for total coliform must be tested for e. Coli

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State Regulations

- 0400-45-1-.06(4) Microbiological
  - (a)1. If you collect 40 samples/month, no more than 5% can be positive to be in compliance
  - (a)2. If you collect less than 40 samples/month, no more than 1 sample can be positive to be in compliance
  - (c) If any routine or repeat sample test (+) for total coliform, it must be analyzed for fecal or *E. coli*

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State Regulations

- 0400-45-1-.07(2) Repeat Monitoring
  - (a) If a routine sample is total coliform positive, the system must collect a set of repeat samples within 24 hours of being notified of the positive result. 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.

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State Regulations

- 0400-45-1-.07(2) Repeat Monitoring
  - (b) The system must collect one at original site, at least one repeat within five service connections upstream and at least one repeat within five service connections downstream
  - (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.)

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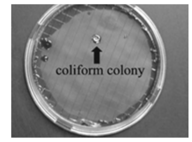
Testing



Membrane Filter Technique

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

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Chlorine Residual

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

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Chlorine Free Residual

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

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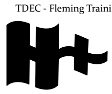
pH



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

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pH

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

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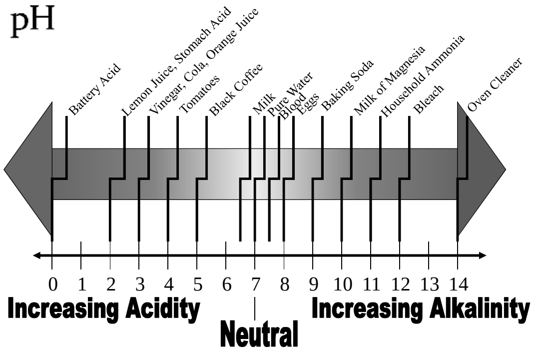
pH



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Fluoride

- Added to drinking water for the reduction of dental caries (cavities)
- Interferences
- Primary MCL = 4.0 mg/L
- Secondary MCL = 2.0 mg/L
- State of Tennessee recommends 0.7 mg/L
  - Fluoridation of drinking water in the state of Tennessee is not required

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Fluoride

- Methods
  - SPADNS
    - interferences are more common with this test
    - alum or aluminum complexes can interfere
  - Electrode
    - TISAB removes most of the aluminum interferences
      - Total Ionic Strength Adjustment Buffer
      - Contains CDTA – used to tie up interferences
    - store probe in a standard, the higher the better
    - probes can last 3-5 years
    - can clean with toothpaste

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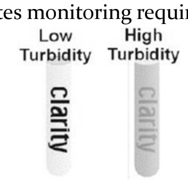
Turbidity

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



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Turbidity

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

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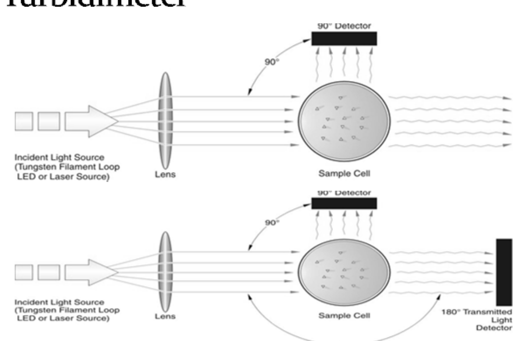
Turbidimeter



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Alkalinity

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

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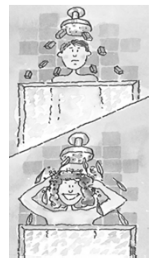
Hardness



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

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Iron and Manganese

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

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Lead and Copper Rule

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

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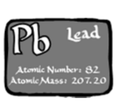
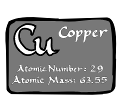
Lead and Copper Rule

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





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Phosphates

- <u>Orthophosphates</u> work well for lead and copper protection
- <u>Polyphosphates</u> work as *sequestering agents* – tie up iron and manganese to prevent color and taste complaints
  - Tie up calcium carbonate as a catalyst
  - Calcium (from alkalinity) is required as a catalyst
  - If low alkalinity, need a blend of polyphosphate and orthophosphate
  - Orthophosphate coats pipe; polyphosphate sequesters

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THM

- Trihalomethane
  - Chloroform
  - Dibromochloromethane
  - Bromodichloromethane
  - Tribromomethane

- MCL = 0.080 mg/L

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HAA5

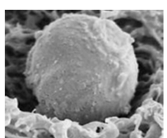
- Haloacetic acids
  - Monochloracetic acid
  - Dichloroaecitic acid
  - Trichloroacetic acid
  - Monobromoacetic acid
  - Dibromoacetic acid

- MCL = 0.060 mg/L

44

Cryptosporidium (Crypto)

- Protozoan parasite
- Common in surface water
- Resistant to traditional disinfectants
- Can pass through filters
- Causes cryptosporidiosis
- Filtration and alternative disinfectants can remove and/or inactivate



Cryptosporidium Oocyst

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Lab Safety

- Read SDS for all chemicals used in lab
- Store chemicals properly
- Know where safety equipment is stored
- Never pour water into acid
- CPR and First Aid Training (TOSHA requirement)
- Clean chemical spills immediately
- Follow published lab procedures (*Standard Methods*)
- Read and become familiar with Safety SOP

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Lab Safety

Safety Data Sheets (SDS)

- Keep on file for all chemicals purchased
  - According to the Americans with Disabilities Act of 1990, MSDS's should be kept for a minimum of 30 years
- Includes all information shown on chemical label and more

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Lab Safety

Safety Data Sheets (SDS)

- Must be readily available for employee review at all times you are in the work place
  - The can't be locked in an office or filing cabinet to which you don't have access to
  - If they are on a computer, everyone must know how to access them
- If you request to see an SDS for a product you use at work and your employer can't show it to you, after one working day you have the right refuse to work with that product until you are shown the correct SDS

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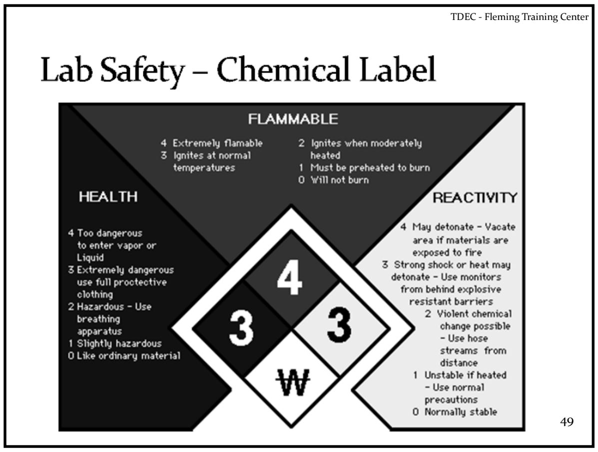
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Lab Safety – Chemical Label
FLAMMABLE
4 Extremely flamable
3 Ignites at normal temperatures
2 Ignites when moderately heated
1 Must be preheated to burn
0 Will not burn
HEALTH
4 Too dangerous to enter vapor or Liquid
3 Extremely dangerous use full proctective clothing
2 Hazardous – Use breathing apparatus
1 Slightly hazardous
0 Like ordinary material
REACTIVITY
4 May detonate – Vacate area if materials are exposed to fire
3 Strong shock or heat may detonate – Use monitors from behind explosive resistant barriers
2 Violent chemical change possible – Use hose streams from distance
1 Unstable if heated – Use normal precautions
0 Normally stable
4
3
3
W
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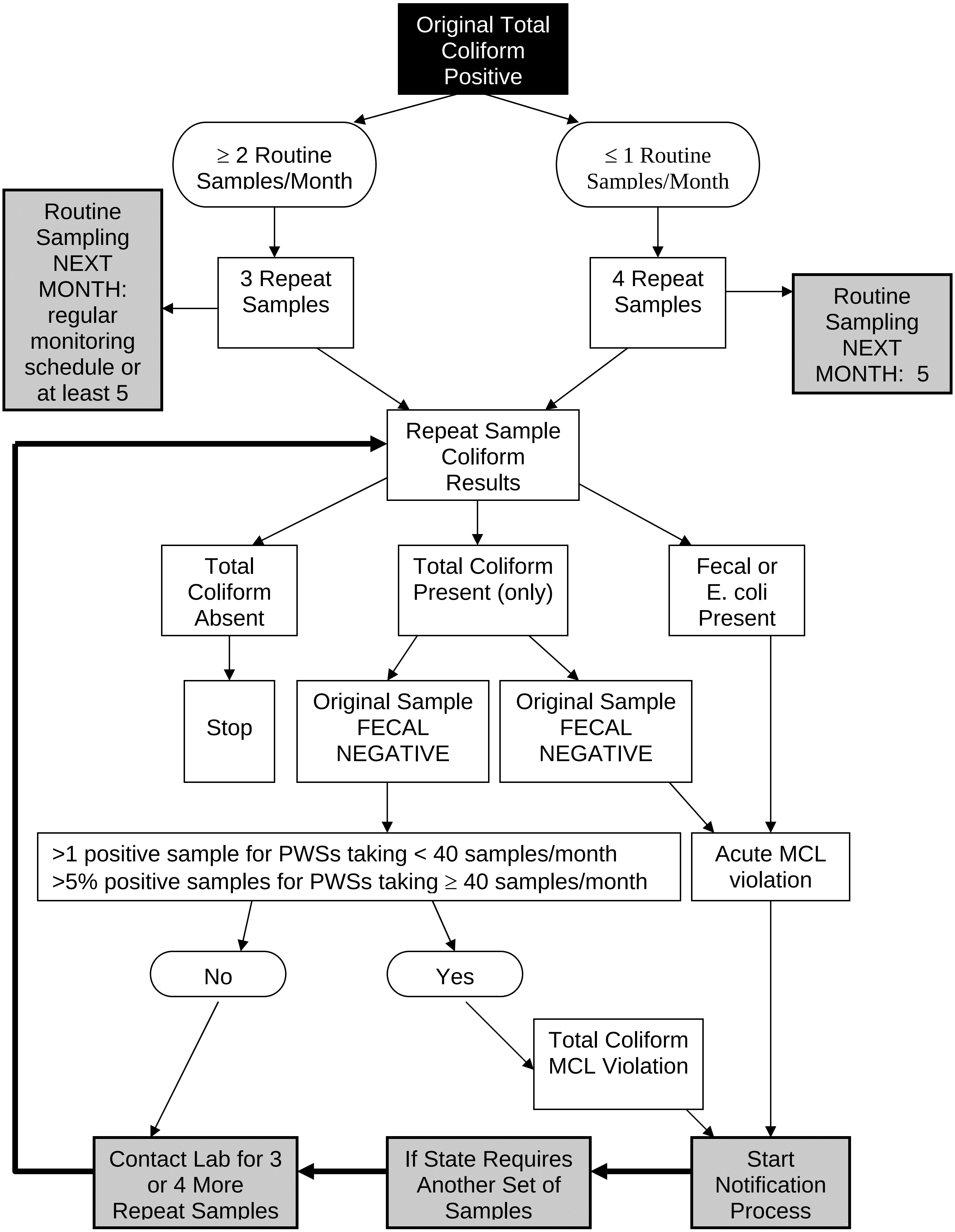
Total Coliform Action Flow Chart



Small Water Systems
Laboratory Practice Quiz

1. The MCL for total coliform bacteria is based on their ______________ .
   a. Concentration in mg/L
   b. Concentration in colonies per 100 mL
   c. Presence or absence
   d. All of the above
   e. None of the above

2. The sample volume to be used when running a membrane filter test for coliform bacteria is _______________ .
   a. 20 mL
   b. 40 mL
   c. 60 mL
   d. 80 mL
   e. 100 mL

3. Records of bacteriological analyses must be kept at least ________________ .
   a. Until the next sanitary survey
   b. Three years or until the next sanitary survey
   c. Five years
   d. Ten years
   e. Twelve years

4. Analysis of samples for determining bacteriological quality of the water must be started within _____________ hours of collection.
   a. 24
   b. 30
   c. 36
   d. 42
   e. 48

5. A bacteriological bottle contains a white powder which is placed in the bottle in order to _________________ .
   a. Keep the bottle clean
   b. Kill any bacteria present
   c. Remove any chlorine residual
   d. All of the above
   e. None of the above

6. Any sample that contains coliform bacteria is a __________________ sample.
   a. Grab
   b. Negative
   c. Positive
   d. Representative
   e. Routine

7. Any sample that does not contain coliform bacteria is a _________________ sample.
   a. Grab
   b. Negative
   c. Positive
   d. Representative
   e. Routine

8. For bacteriological sample to be useful, it must contain essentially the same constituents as the body of water from which it was taken. This type of sample is called a _________________ sample.
   a. Grab
   b. Flow-proportional time composite
   c. Representative
   d. Time composite

9. To remove any stagnant water from the customer's service line, and to make certain that water from the distribution main is being sampled, flush the faucet for ________ minutes.
   a. 1 – 3
   b. 2 – 5
   c. 5 – 7
   d. 7 – 9
   e. 10 – 15

10. Bottles for collecting samples for bacteriological analyses should ______________ .
    a. Not be rinsed before use
    b. Be rinsed before use
    c. Be completely filled
    d. All of the above
    e. None of the above
11. Bottles for collecting samples for bacteriological analyses contain ______________, which destroys any chorine residual in the sample.
    a. Sodium arsenite
    b. Sodium chloride
    c. Sodium fluoride
    d. Sodium hydroxide
    e. Sodium thiosulfate

12. Samples for bacteriological analysis should not be taken from _________________.
    a. Swivel faucets
    b. Leaking faucets
    c. Faucets with aerators, strainers or hose attachments
    d. All of the above
    e. None of the above

13. A sample which consists of a number of grab samples taken from the same sampling point at different times and mixed together before analysis is called a ___________________ sample.
    a. Composite
    b. Grab
    c. Flow-proportional time composite
    d. Representative
    e. Time composite

15. High fluoride readings can result from all of the following causes except _________.
    a. Polyphosphates can interfere with the SPADNS method, resulting in high fluoride readings
    b. Not accounting for natural fluoride in the water
    c. Dilution of water which has been fluoridated with unfluoridated water in storage tanks
    d. All of the above
    e. None of the above

16. What is the secondary maximum contaminant level for fluoride?
    a. 0.2 mg/L
    b. 0.4 mg/L
    c. 2.0 mg/L
    d. 4.0 mg/L

17. The maximum permissible level of a contaminant in water as specified in the regulations of the Safe Drinking Water Act is the ___________________________ .
    e. Maximum contaminant level
    f. Saturation point
    g. Zeta potential
    h. All of the above
    i. None of the above

18.____________________ is an indicator used when measuring the total alkalinity concentration on a water sample.
    j. EDTA
    k. Eriochrome black-T
    l. Bromcresol Green Methyl Red
    m. Phenolphthalein
    n. Sodium thiosulfate

1. C
2. E
3. C
4. B
5. C
6. C
7. B
8. C
9. B
10. A
11. E
12. D
13. E
14. C
15. C
16. A
17. C

Section 9

Regulations

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 Public Acts of 1983, Chapter 324.

(2) The Division of Water Supply is responsible for the supervision of public water systems.

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

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 applicable maximum contaminant levels or treatment technique requirements; in providing

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

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. §§ 68-221-701 et seq. and 4-5-201 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. §§ 68-221-701 et seq. and 4-5-201 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 fifteen (15) service connections used by year round residents or regularly serves at least twenty five (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 regulations shall mean the Division of Water Supply, 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" 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 twenty five (25) of the same persons over six (6) 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" mean reports, proposals, preliminary plans, survey and basis of design data, general and detailed construction plans, profiles, specifications and all other information pertaining to public water system planning.

(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.

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

(78) "Primary Drinking Water Regulation" means a regulation promulgated by the Department which:

(a) applies to public water systems;

(b) specifies contaminants which, in the judgment of the Department, may have any adverse effect on the health of persons;

(c) specified for each such contaminant either;

1. a 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 to (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 such serves 15 or more connections or which regularly serves 25 or more individuals daily at least 60 days out of the year and includes:

(a) any collection, treatment, storage or distribution facility under control of the operator of such system and used primarily in connection with such system; and

(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.

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

(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.

(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" mean a regulation promulgated by the Department which applies to public water systems and which specifies the maximum contaminant levels which, in the judgment of the Department are requisite to protect the public welfare. Such regulations may apply to any contaminant in drinking water

(a) which may adversely affect the odor or appearance of such water and consequently may cause the persons served by the public water system providing such water to discontinue its use, or

(b) which may otherwise adversely affect the public welfare. Such regulations may vary according to geographic and other circumstances.

(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).

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

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

(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 twenty-five (25) individuals daily at least sixty (60) days out of the year. A transient non community water system is a public water supply system that generally serves a transient population such as hotels, motels, restaurants, camps, service stations churches, industry, and rest stops.

(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 regulations.

(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. §§ 68-221-701 et seq. and 4-5-201 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.*

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.

(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 Supply 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 Supply. This shall be done within 10 days of the local government's approval. The commissioner may periodically review the unit of local government's plans review program and prescribe changes as deemed appropriate. The Division of Water Supply may execute a written agreement with a unit of local government which has received plans review certification. Failure to comply with the terms of the agreement may result in revocation of the plans review certification.

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

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
8.	Heptachlor	0.0004
9.	Heptachlor epoxide	0.0002
10.	Lindane	0.0002
11.	Methoxychlor	0.04
12.	Polychlorinated biphenyls	0.0005
13.	Toxaphene	0.003
14.	2,4,5 Trichlorophenoxyproprionic acid	0.05
15.	Pentachlorophenol	0.001
16.	Benzo(a)pyrene	0.0002
17.	Dalapon	0.2
18.	Di(2-ethylhexyl) adipate	0.4
19.	Di(2-ethylhexyl)phthalate	0.006
20.	Dinoseb	0.007
21.	Diquat	0.02
22.	Endothall	0.1
23.	Glyphosate	0.7
24.	Hexachlorobenzene	0.001
25.	Hexachlorocyclopentadiene	0.05
26.	Oxamyl (Vydate)	0.2
27.	Picloram	0.5
28.	Simazine	0.004

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

29.	2,3,7,8-TCDD (Dioxin)	0.00000003
30.	Endrin	0.002

(3) Turbidity - The requirements of paragraph (3) of Rule 0400-45-01-.06 apply to filtered surface systems until June 29, 1993. The requirements in this paragraph apply to unfiltered systems that the Department has determined, in writing, must install filtration until June 29, 1993, or until filtration is installed, whichever is later.

The maximum contaminant level for turbidity is applicable to public water systems using surface water source(s) in whole or in part. Furthermore, the maximum contaminant level for turbidity is applicable to those systems using ground water which are required to install turbidimeters pursuant to paragraph (11) of Rule 0400-45-01-.05. The maximum contaminant levels for turbidity in drinking water, measured at a representative entry point(s) to the distribution system are:

(a) One (1.0) turbidity unit, as determined by monthly average pursuant to 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

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

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.

2. The Department has the discretion to allow a public water system, on a case-by-case basis, to forgo fecal coliform or E. coli testing on a total coliform-positive sample if that system assumes that the total coliform-positive sample is fecal coliform-positive or E. coli-positive. Accordingly, the system must notify the Department as specified in part 1 of this subparagraph and the provisions of subparagraph (b) of this paragraph apply.

(d) A public water system must determine compliance with the MCL for total coliforms in subparagraph (a) and (b) of this paragraph for each month in which it is required to monitor for total coliforms.

(e) No variance or exemptions from the maximum contaminant level for total coliforms are permitted.

(f) Maximum contaminant level goals for microbiological contaminants.

1. MCLGs for the following contaminants are as indicated:

	Contaminant	MCLG
(i)	*Giardia lamblia*	zero
(ii)	Viruses	zero
(iii)	*Legionella*	zero
(iv)	Total coliforms (including fecal coliforms and *Escherichia coli*)	zero
(v)	*Cryptosporidium*	zero
(vi)	*Escherichia coli (E. coli)*	zero

2. The MCLG identified in subpart 1(iv) of this subparagraph is no longer applicable beginning April 1, 2016.

(g) Beginning April 1, 2016, a system is in compliance with the MCL for E. coli for samples taken under the provisions of Rule 0400-45-01-.41 unless any of the conditions identified in parts 1 through 4 of this subparagraph occur. For purposes of the public notification requirements in Rule 0400-45-01-.19, violation of the MCL may pose an acute risk to health.

1. The system has an E. coli-positive repeat sample following a total coliform positive routine sample.

2. The system has a total coliform positive repeat sample following an E. coli-positive routine sample.

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

3. The system fails to take all required repeat samples following an E. coli-positive routine sample.

4. The system fails to test for E. coli when any repeat sample tests positive for total coliform.

(h) Until March 31, 2016, a public water system must determine compliance with the MCL for total coliforms in subparagraphs (a) and (b) of this paragraph for each month in which it is required to monitor for total coliforms. Beginning April 1, 2016, a public water system must determine compliance with the MCL for E. coli in subparagraph (g) of this paragraph for each month in which it is required to monitor for total coliforms.

(i) The EPA 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 level for total coliforms in subparagraphs (a) and (b) of this paragraph and for achieving compliance with the maximum contaminant level for E. coli in subparagraph (g) of this paragraph:

1. Protection of wells from fecal contamination by appropriate placement and construction;

2. Maintenance of a disinfectant residual throughout the distribution system;

3. Proper maintenance of the distribution system including appropriate pipe replacement and repair procedures, main flushing programs, proper operation and maintenance of storage tanks and reservoirs, cross connection control, and continual maintenance of positive water pressure in all parts of the distribution system;

4. Filtration and/or disinfection of surface water, as described in Rules 0400-45-01-.17, 0400-45-01-.31 and 0400-45-01-.39, or disinfection of ground water, as described in Rule 0400-45-01-.40, using strong oxidants such as chlorine, chlorine dioxide, or ozone; and

5. For systems using ground water, compliance with the requirements of an EPA-approved State Wellhead Protection Program developed and implemented under section 1428 of the Federal Safe Drinking Water Act.

(j) The EPA Administrator, pursuant to section 1412 of the Federal Safe Drinking Water Act, hereby identifies the technology, treatment techniques, or other means available identified in subparagraph (i) of this paragraph as affordable technology, treatment techniques, or other means available to systems serving 10,000 or fewer people for achieving compliance with the maximum contaminant level for total coliforms in subparagraphs (a) and (b) of this paragraph and for achieving compliance with the maximum contaminant level for E. coli in subparagraph (g) of this paragraph.

(5) Radionuclides-

(a) The following maximum contaminant levels for radium-226, radium-228, and gross alpha particle radioactivity are applicable to all community water systems:

1. Combined radium-226 and radium-228: The maximum contaminant level for combined radium-226 and radium-228 is 5 pCi/L. The combined radium-226 and radium-228 value is determined by the addition of the results of the analysis for radium-226 and the analysis for radium-228.

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

Bromate	Control of ozone treatment process to reduce production of bromate
Chlorite	Control of treatment processes to reduce disinfectant demand and control of disinfection treatment processes to reduce disinfectant levels

(b) TTHM and HAA5.

1. Running Annual Average compliance (Rule 0400-45-01-.36)

(i) Compliance dates. Subpart H systems serving 10,000 or more persons must comply with this part 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 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;

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

	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 Haloacetic acids (five) - (HAA5).	Systems serving 10,000 or more: 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.

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

persons may collect all required samples on a single day if they are taken from different sites.

(f) A public water system that uses surface water or ground water under the direct influence of surface water, and does not practice filtration in compliance with Rule 0400-45-01-.31 must collect at least one sample near the first service connection each day the turbidity level of the source water exceeds 1 NTU. This sample must be analyzed for the presence of total coliforms. When one or more turbidity measurements in any day exceed 1 NTU, the system must collect this coliform sample within 24 hours 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.)

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

.06(4)(c) that was initiated by a total coliform-positive sample taken before April 1, 2016, is completed, as well as analytical method, reporting, recordkeeping, public notification, and consumer confidence report requirements associated with that monitoring and testing. Beginning April 1, 2016, the provisions of Rule 0400-45-01-.41 are applicable, with systems required to begin regular monitoring at the same frequency as the system specific frequency required on March 31, 2016.

Authority: *T.C.A. §§ 68-221-701 et seq. and 4-5-201 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-.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

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

Authority: *T.C.A. §§ 68-221-701 et seq. and 4-5-201 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

	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. §§ 68-221-701 et seq. and 4-5-201 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. §§ 68-221-701 et seq. and 4-5-201 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. §§ 68-221-701 et seq. and 4-5-201 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. §§ 68-221-701 et seq. and 4-5-201 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) All community water systems which are designated as a surface supply and classified as a filtration system and all iron removal plants which use gravity filters must have an operator in attendance and responsible for the treatment process when the plant is in operation. Gravity iron removal plants which have installed continuous monitoring equipment including equipment for turbidity and chlorine residual with alarms and/or shutdown ability may seek approval from the Department to operate the treatment plant in an automated mode without an operator in attendance. All iron removal plants with pressure filters and using a ground water source from an approved sand and gravel formation will not be required to have an operator in attendance during all periods of operation provided suitable protection, acceptable to the Department, is provided.

Non–community water systems which are classified as a surface supply will be required to have a full time operator in attendance unless certain continuous monitoring equipment is installed.

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

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 same.

Because the proper operation and maintenance of water systems is critical to a system's ability to provide safe water to the public and to comply with these rules, all water supply systems must comply with the provisions of Chapter 0400-49-01. A violation of those rules is a violation of this rule as well.

(2) All community water systems and those non-community water systems classified as a surface source shall compile and maintain accurate daily operating records of the water works system on forms prepared and furnished by the Department. The daily operating records shall be submitted in a timely manner so they are received by the Department no later than 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.

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

(3) All water quality tests, other than those listed in 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.

(6) 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

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

operation of such cross–connection, auxiliary intake, or bypass has been approved by the Department. The arrangement of sewer, soil, or other drain lines or conduits carrying sewage or other wastes in such a manner that the sewage or waste may find its way into any part of the public water system is prohibited.

All community water systems must adopt an ordinance or policy prohibiting all of the above and submit a copy of the executed ordinance or policy to the Department for approval. All community water systems shall develop a written plan for a cross–connection control program to detect and eliminate or protect the system from cross–connections. The written plan must be approved by the Department.

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

(a) Public water systems must develop and implement an ongoing cross-connection program. Cross-connection plans and policies shall present all information in conformance with the “Design Criteria for Community Public Water Systems” as published by the Department.

(b) The public water system shall ensure that cross-connections between the distribution system and a consumer’s plumbing are surveyed and/or inspected and determined not to exist or contain a significant risk or are eliminated or controlled by the installation of an approved backflow preventer commensurate with the degree of hazard.

(7) All community water system 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 by the Department. Systems shall include a drought management plan as a part of the emergency operations plan. The drought management plans 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.

(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, filters and wells. In lieu of writing their own disinfection standard operating procedures, public water systems, engineers and contractors may chose to follow the latest edition of the AWWA standards C-651, C-652 or equivalent methods provided the method has been approved in writing by the department and is available during the inspection, construction, maintenance or repair activity. The documentation shall include bacteriological sample results, construction logs, standard operating procedures and may include photographs where appropriate. All pipes, tanks, filters, filter media and other materials shall be properly disinfected prior to being placed in service. Any disinfectant used to disinfect shall be NSF approved or plain household bleach and used in a manner that assures sufficient contact time and concentration to inactivate any pathogens present. Bacteriological results including line

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

repair records indicating adequacy of disinfection shall be maintained on file by the water system for five years. All public water systems, contractors, and engineers shall prepare and follow standard disinfection procedures approved by the Department when inspecting, maintaining, repairing or constructing lines, tanks, filters and wells. Procedures to ensure that water containing excessive concentrations of disinfectant is not supplied to the customers or discharged in such manner as to harm the environment shall be implemented.

All materials used for new or repaired water lines, storage facilities, filters, filter media, and wells will be inspected prior to use for any evidence of gross contamination. Any contamination observed shall be removed and the materials protected during installation.

(b) Disinfection of New Facilities-Bacteriological samples will be collected and analyzed to verify the effectiveness of the disinfection practices prior to placing new facilities in service. Bacteriological samples shall be collected to determine the effectiveness of the installation process including protecting the pipe material during storage, installation, and disinfection. This can be demonstrated by collecting two sets of microbiological samples 24 hours apart or collecting a single set of microbiological samples 48 hours or longer after flushing the highly chlorinated water from the lines. In either case microbiological samples in each set will be collected at approximately 2,500-foot intervals with samples near the beginning point and at the end point unless alternate sampling frequency and distance between sampling points approval has been obtained from the Department. Where sanitary conditions were not maintained before, during or after construction, an additional bacteriological sample shall be collected from a location representing the water from the contaminated area. Unsanitary conditions include failure to document the sanitary handling of materials, to conduct construction inspections and to maintain records, and to document sanitary practices during construction and other hazards such trench flooding during construction. If the constructed facility yields positive bacterial samples, additional flushing, disinfection and bacteriological sampling shall be repeated until the water is coliform free.

(c) Disinfection of Existing Facilities-Drinking water mains, storage facilities and filters that have been partially dewatered during inspection or repair shall, after the repair or inspection is completed, be disinfected, and flushed prior to placing it back in service. Bacteriological samples shall be collected immediately or as soon as possible after the repair is completed and from a location representing the water contained in the repaired line, tank or filter. The repaired facility may be returned to service prior to obtaining bacteriological results. If the repaired facility yields positive bacterial samples, additional flushing, disinfection and bacteriological sampling shall be repeated until the water is coliform free.

1. If one-half or more of either the original or repeat bacteriological samples collected from the repaired or renovated facility are total coliform positive, the system shall notify the 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.

2. If any public water system collects a fecal coliform positive repeat sample or e-coli positive repeat sample or a total coliform positive repeat sample following an initial positive fecal coliform or e-coli sample collected from the repaired or renovated facility, the system shall notify the Department within 24-hours and issue a tier 1 public notice using the language specified in Appendix B of Rule 0400-45-01-.19.

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

(d) Inspectors, contractors, operators, public water systems or engineers that fail to document and follow adequate disinfection procedures, and fail to collect bacteriological samples during repairs, inspections or maintenance activities that potentially would compromise the microbial quality of the water shall issue a boil water advisory to the customers served by that portion of the public water system prior to returning the facility to service. The boil water advisory shall remain in effect until satisfactory microbial tests results are obtained.

(9) All community water systems shall be operated and maintained to provide minimum positive pressure of twenty (20) psi throughout the distribution system. No person shall install or maintain a water service connection to any premises where a booster pump has been installed unless such booster pump is equipped with a low pressure cut-off mechanism designed to cut off the booster pump when the pressure on the suction side of the pump drops to twenty (20) psi gauge.

(10) All community water systems having more than 50 service connections shall establish and maintain an adequate flushing program. The flushing program established shall help ensure that dead end and low usage mains are flushed periodically, drinking water standards are met, sediment and air removal and the free chlorine residual specified under 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 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.

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

There must be 30 inches of sand media with an effective size of 0.35 mm to 0.55 mm and a uniformity coefficient not greater than 1.70

(b) High Rate Filtration - 4.0 gallons per minute per square foot for turbidity removal, 4.0 gallons per minute per square foot for iron removal.

There must be 30 inches of dual media with 10 to 12 inches of sand and 18 to 20 inches of anthracite. The sand shall have an effective size of 0.35 mm to 0.55 mm and a uniformity coefficient not greater than 1.70. The anthracite shall have an effective size of 0.8 mm to 1.2 mm with a uniformity coefficient not greater than 1.85.

(c) Existing water systems with rapid sand filters and approved for higher rates of filtration by the Department will be allowed to continue at that rate provided the drinking water standards are met. The water supplier must be able to document that the Department approved the system for the higher rate.

(d) All mixed media filter beds will be at least 30 inches in depth and approved by the Department.

(e) Filtration rates above 4.0 gallons per minute per square foot will be considered on an individual basis. The Department will take into account the raw water characteristics, the treatment units, operational history, and operating personnel.

(13) All community water systems serving 50 connections or more shall install duplicate pumps for the raw water, finished water, and distribution pumping stations. A water system will not be required to have duplicate pumps in a distribution pumping station under the following conditions: limited number of service connections, availability of replacement pumps, maintaining adequate flows and pressures without the pumping station, and for emergency use only. All community public water systems using ground water supplies and having more than 50 service connections must have duplicate wells and/or duplicate pumps in a spring supply unless fed by gravity flow.

(14) All community water systems serving 50 connections or more are required to have 24 hours of distribution storage based on the average daily demand for the past twelve months. Distribution storage must be located so that the instantaneous demand can be met in all areas at any time.

(a) Systems which purchase water for resale may utilize the storage of the supplier provided the supplier has adequate distribution storage. Water systems that have large ground storage tanks will be given credit for distribution storage provided auxiliary power is available to pump water to the distribution system.

(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.

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

(d) Public water systems which utilize wells and provide only disinfection, pH adjustment, corrosion inhibitor and/or fluoridation as treatment, may use the capacity of the wells and the plant as part of the distribution storage under the following conditions:

1. The existing distribution storage tank(s) are adequate to meet the peak demands on the system,

2. The well(s), disinfection equipment and other pumping facilities needed to supply water to the distribution storage tank are equipped with an auxiliary power source with automatic controls, and

3. The well field capacity is determined by removing the largest well from consideration.

(e) Public water systems may take into account private distribution storage facilities in the following manner:

1. Private distribution storage may be counted as water system storage provided the private storage tank floats on the water utility's system and the water used serves both the private and utility system demand.

2. The water utility may reduce the amount of needed distribution storage by subtracting the average daily volume of any water user that has its own storage tank. This can be done provided the private storage tank is used on a daily basis.

3. Private distribution storage tanks used strictly for fire protection by the private owner cannot be in the water systems distribution storage capacity.

(15) All community water systems serving 50 or more service connections must have and maintain up-to-date maps of the distribution system. These maps must show the locations of the water mains, sizes of mains, valves, blow-offs or flush hydrants, air-release valves, and fire hydrants. One up-to-date copy of the overall system distribution map(s) is to be submitted to the Division of Water Supply every five years.

(16) All vents on wells, springs, storage tanks, overflows and clearwells shall be properly screened. All overflows on springs and tanks shall be screened and protected.

(17) All buildings and equipment used in and for the production and distribution of water (to include chemical and other storage buildings) must be well maintained and be reliable and fit for the purpose for which they are used. This includes, but is not limited to:

(a) When a water treatment plant is not producing water and an operator is not in attendance, plant entrances must be locked.

(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.

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

(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 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. The recommended level of fluoridation in the finished water is 0.7 mg/l. Any public water system which determines to cease fluoridation treatment of its water supply shall notify the local environmental field office within the department of environment and conservation and the commissioner of the department of health of its decision to discontinue fluoridation 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:

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

(a) At least 99.9 percent (3 log) removal and/or inactivation of Giardia lamblia cysts between a point where the raw water is not subject to recontamination by surface water runoff and a point downstream before or at the first customer.

(b) At least 99.99 percent (4 log) removal and/or inactivation of viruses between a point where the raw water is not subject to recontamination by surface water runoff and a point downstream before or at the first customer.

(28) All public water systems using surface water shall provide disinfection to control the biological quality of the water. Due consideration shall be given to the contact time of the disinfectant in the water with relation to pH, ammonia, taste producing substances, temperature, presence and type of pathogens, and trihalomethane formation potential. All disinfection basins must be designed to prevent water short-circuiting the system. The disinfectant will be applied in the manner needed to provide adequate contact time.

(29) All community water systems using ground water as the raw water source serving water to more than 50 connections or 150 people will apply the disinfectant in the manner needed for adequate contact time. Contact time for ground water systems shall not be less than 15 minutes prior to the first customer.

(30) Any surface supplied public water system or ground water systems under the direct influence of surface water required to filter shall employ filtration in combination with disinfection that will achieve 99.9% (3 log) and 99.99% (4 log) inactivation of Giardia lamblia and viruses respectively between a point where the raw water is not subject to recontamination by surface water runoff and a point downstream before or at the first customer. For the purposes of determining removal or inactivation efficiencies for Giardia lamblia and viruses Table 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

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

	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.

(32) New service taps on existing mains that must be uncovered to make the tap, shall be flushed and the free chlorine residual measured and recorded prior to connecting the service lines. These records shall be retained until the next sanitary survey or for three years.

(33) All public water systems shall properly maintain their distribution system finished water storage tanks. Each community water system shall establish and maintain a maintenance file on each of its finished water and distribution storage tanks. These maintenance files must be available for inspection by Department personnel. These files must include the dates and results of all routine water storage tank inspections by system personnel, any reports of detailed professional inspections of the water storage tanks by contractor personnel, dates and details of routine tank cleanings and surface flushings, and dates and details of all tank maintenance activities. The tank inspection records shall include dates of the inspections; the sanitary, coating and structural conditions of the tank; and all recommendations for needed maintenance activities. Community Water Systems shall have a professional inspection performed and a written report produced on each of their finished water and distribution storage tanks at least once every five years. Non-community water systems shall have a professional inspection and written report performed on each of their atmospheric pressure finished water and distribution storage tanks no less frequently than every five years. Records of these inspections shall be available to the Department personnel for inspection. Persons conducting underwater inspections of finished water storage tanks shall comply with AWWA standard C652-92 or later versions of the standard.

(34) Paints and coatings for the interior of potable water storage facilities must be acceptable to the Department. Paints and coatings accepted by the Environmental Protection Agency (EPA) and/or the National Sanitation Foundation (NSF) for potable water contact are generally acceptable to the Department. Paint systems for steel tanks shall be consistent with AWWA Standard D102-78. Factory coated bolted steel tanks shall be in accordance with AWWA D103-87. Wire-wound circular prestressed concrete tanks shall be in accordance with AWWA D110-86.

(35) By January 1, 1996, public water systems using surface water and ground water systems under the direct influence of surface water that filter shall have rewash capability. Such systems shall perform a rewash cycle, or filter to waste each time a filter is backwashed. The

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

rewash cycle shall be conducted in a way and manner necessary to prevent the introduction of contaminants such as pathogens and turbidity trapped in the filter into the clear well or distribution system.

Existing filter plants may be approved to operate without rewash (filter-to-waste provisions) if existing operational and backwash practices prevent water of unacceptable quality from entering the clearwell or distribution system. To operate without rewash the water system must demonstrate to the Department that filtered water turbidity after backwashing is reliably and consistently below 0.5 NTU immediately after backwashing each filter. Approval to operate without rewash must be approved in writing and approval must be renewed if any modifications are made to the operation or design of the plant. Each filter that operates without rewash must have a continuous recording turbidimeter and retain the records for a period of five years.

(36) By January 1, 1995, all chemicals, additives, coatings or other materials used in the treatment, conditioning and conveyance of drinking water must have been approved by the National Sanitation Foundation (NSF) or American National Standards Institute (ANSI) certified parties as meeting NSF product standard 60 and 61. Until 1995, products used for treatment, conditioning and conveyance of drinking water shall have been listed as approved by the US EPA or NSF.

(37) Any new Community Water System or Non-Transient Non-Community Water System commencing operation after September 30, 1999 shall have a “Capacity Development Plan” and be a “viable water system.”

(38) Public Water Systems identified as not complying or potentially not complying with the requirements of the Safe Drinking Water Act and in accordance with the priorities established in the 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 turbidimeters are primary standards and materials suggested by the manufacturer such as sealed sample cells filled with metal oxide particles in a polymer gel. The 0.5 NTU ICE-PIC™ from Hach is an approved reference material for secondary turbidity verifications for Hach continuous

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

turbidimeters when utilized as per Manufacturers' recommendations. 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. §§ 68-221-701 et seq. and 4-5-201 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-.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

(Rule 0400-45-01-.19, continued)

Table 0400-45-01-.19(1)(a)

Violation Categories and Other Situations
Requiring a Public Notice

1. NPDWR violations:

   (i) Failure to comply with an applicable maximum contaminant level (MCL) or maximum residual disinfectant level (MRDL).
   (ii) Failure to comply with a prescribed treatment technique (TT).
   (iii) Failure to perform water quality monitoring, as required by the drinking water regulations.
   (iv) Failure to comply with testing procedures as prescribed by a drinking water regulation.

2. Variance and exemptions under sections 1415 and 1416 of SDWA:

   (i) Operation under a variance or an exemption.
   (ii) Failure to comply with the requirements of any schedule that has been set under a variance or exemption.

3. Special public notices:

   (i) Occurrence of a waterborne disease outbreak or other waterborne emergency.
   (ii) Exceedance of the alternate MCL for nitrate by non-community water systems (NCWS), where the non-community system has been granted an alternate standard by the department.
   (iii) Exceedance of the secondary maximum contaminant level (SMCL) for fluoride.
   (iv) Availability of unregulated contaminant monitoring data.
   (v) Other violations and situations determined by the department to require a public notice under this rule, not already listed in Appendix A.

(b) Public notice requirements are divided into three tiers to take into account the seriousness of the violation or situation and any potential adverse health effects that may be involved. The public notice requirements for each violation or situation listed in Table 0400-45-01-.19(1)(a) are determined by the tier to which it is assigned. Table 0400-45-01-.19(1)(b) provides the definition of each tier. Appendix A of this rule identifies the tier assignment for each specific violation or situation.

Table 0400-45-01-.19(1)(b)

Definition of Public Notice Tiers

1. Tier 1 public notice-required for NPDWR violations and situations with significant potential to have serious adverse effects on human health as a result of short-term exposure.

2. Tier 2 public notice--required for all other NPDWR violations and situations with potential to have serious adverse effects on human health.

3. Tier 3 public notice--required for all other NPDWR violations and situations not included in Tier 1 and Tier 2.

(c) Who must be notified?

(Rule 0400-45-01-.19, continued)

1. Each public water system must provide public notice to persons served by the water system, in accordance with this rule. Public water systems that sell or otherwise provide drinking water to other public water systems (i.e., to consecutive systems) are required to give public notice to the owner or operator of the consecutive system; the consecutive system is responsible for providing public notice to the persons it serves.

2. If a public water system has a violation in a portion of the distribution system that is physically or hydraulically isolated from other parts of the distribution system, the Department may allow the system to limit distribution of the public notice to only persons served by that portion of the system which is out of compliance. Permission by the department for limiting distribution of the notice must be granted in writing.

3. A representative copy of the each type of the notice distributed, published, posted and/or made available to the persons served by the system and/or to the media must also be sent to the Department within ten days of completion of each public notification.

(2) Tier 1 Public Notice-Form, manner, and frequency of notice.

(a) Violation of the MCL for total coliforms when fecal coliform or E. coli are present in the water distribution system as specified in Rule 0400-45-01-.06, or when the water system fails to test for fecal coliforms or E. coli when any repeat sample tests positive for coliform as specified in Rule 0400-45-01-.07; Violation of the MCL for E. coli (as specified in Rule 0400-45-01-.06(4)(f));

Table 0400-45-01-.19(2)(a)

Violation Categories and Other Situations
Requiring a Tier 1 Public Notice

1. Violation of the MCL for total coliforms when fecal coliform or E. coli are present in the water distribution system as specified in Rule 0400-45-01-.06, or when the water system fails to test for fecal coliforms or E. coli when any repeat sample tests positive for coliform as specified in Rule 0400-45-01-.07;

2. Violation of the MCL for nitrate, nitrite, or total nitrate and nitrite, as defined in Rule 0400-45-01-.06, or when the water system fails to take a confirmation sample within 24 hours of the system's receipt of the first sample showing an exceedance of the nitrate or nitrite MCL, as specified in Rule 0400-45-01-.09;

3. Exceedance of the alternate MCL for nitrate by non-community water systems (NCWS), where the non-community system has been granted an alternate standard by the department;

4. Violation of the MRDL for chlorine dioxide, as defined in Rule 0400-45-01-.36, when one or more samples taken in the distribution system the day following an exceedance of the MRDL at the entrance of the distribution system exceed the MRDL, or when the water system does not take the required samples in the distribution system, as specified in Rule 0400-45-01-.36;

5. Violation of the turbidity MCL under Rule 0400-45-01-.06, where the department determines after consultation that a Tier 1 notice is required or where consultation does not take place within 24 hours after the system learns of the violation;

(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)

health. When consultation does not take place within the 24-hour period, the water system must distribute a Tier 1 notice of the violation within the next 24 hours (i.e., no later than 48 hours after the system learns of the violation), following the requirements under subparagraphs (2)(b) and (c) of this rule. Consultation with the department is required for:

(i) Violation of the turbidity MCL under Rule 0400-45-01-.06; or

(ii) Violation of the SWTR, IESWTR or LT1ESWTR treatment technique requirement (Rule 0400-45-01-.31) resulting from a single exceedance of the maximum allowable turbidity limit.

(c) What is the form and manner of the Tier 2 public notice? Public water systems must provide the initial public notice and any repeat notices in a form and manner that is reasonably calculated to reach persons served in the required time period. The form and manner of the public notice may vary based on the specific situation and type of water system, but it must at a minimum meet the following requirements:

1. Unless directed otherwise by the department in writing, community water systems must provide notice by:

(i) Mail or other direct delivery to each customer receiving a bill and to other service connections to which water is delivered by the public water system; and

(ii) Any other method reasonably calculated to reach other persons regularly served by the system, if they would not normally be reached by the notice required in subpart (i) of this part. Such persons may include those who do not pay water bills or do not have service connection addresses (e.g., house renters, apartment dwellers, university students, nursing home patients, prison inmates, etc.). Other methods may include: publication in a local newspaper; delivery of multiple copies for distribution by customers that provide their drinking water to others (e.g., apartment building owners or large private employers); posting in public places served by the system or on the Internet; or delivery to community organizations.

2. Unless directed otherwise by the department in writing, non-community water systems must provide notice by:

(i) Posting the notice in conspicuous locations throughout the distribution system frequented by persons served by the system, or by mail or direct delivery to each customer and service connection (where known); and

(ii) Any other method reasonably calculated to reach other persons served by the system if they would not normally be reached by the notice required in subpart (i) of this part. Such persons may include those served who may not see a posted notice because the posted notice is not in a location they routinely pass by. Other methods may include: publication in a local newspaper or newsletter distributed to customers; use of E-mail to notify employees or students; or, delivery of multiple copies in central locations (e.g., community centers).

(4) Tier 3 Public Notice--Form, manner, and frequency of notice.

(a) Which violations or situations require a Tier 3 public notice? Table 0400-45-01-.19(4) lists the violation categories and other situations requiring a Tier 3 public notice.

(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-.31, continued)

1. Representative samples of a system's filtered water effluent must be less than or equal to 1 NTU in at least 95 percent of the measurements taken each month. In systems using slow sand filtration, if the Department determines there is no significant interference with disinfection at a higher turbidity level, the Department may substitute this higher turbidity limit for a system.

2. The turbidity level of representative samples of a system's filtered water must at no time exceed 5 NTU.

(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) The public water system 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.

(Rule 0400-45-01-.31, continued)

[1]The day's samples cannot be taken at the same time. The sampling intervals are subject to Department review and approval.

If at any time the free chlorine concentration falls below 0.2 mg/l in a system using grab sampling in lieu of continuous monitoring, the system must take a grab sample every 4 hours until the free residual concentration is equal to or greater than 0.2 mg/l.

6. Until March 31, 2016, the residual disinfectant concentration must be measured at least at the same points in the distribution system and at the same time as total coliforms are sampled, as specified in paragraph (1) of Rule 0400-45-01-.07. Beginning April 1, 2016, the residual disinfectant concentration must be measured at least at the same points in the distribution system and at the same time as total coliforms are sampled, as specified in paragraphs (4) through (8) of Rule 0400-45-01-.41. The Department may allow a public water system which uses both a surface water source or a ground water source under direct influence of surface water, and a ground water source, to take disinfectant residual samples at points other than the total coliform sampling points if the Department determines that such points are more representative of treated (disinfected) water quality within the distribution system. Heterotrophic bacteria, measured as heterotrophic plate count (HPC) as specified in part (10)(a)4 of Rule 0400-45-01-.14, may be measured in lieu of residual disinfectant concentration.

(c) Until March 31, 2016, the residual disinfectant concentration must be measured at least at the same points in the distribution system and at the same time as total coliforms are sampled, as specified in paragraph (1) of Rule 0400-45-01-.07. Beginning April 1, 2016, the residual disinfectant concentration must be measured at least at the same points in the distribution system and at the same time as total coliforms are sampled, as specified in paragraphs (4) through (8) of Rule 0400-45-01-.41. The Department may allow a public water system which uses both a surface water source or a ground water source under direct influence of surface water, and a ground water source, to take disinfectant residual samples at points other than the total coliform sampling points if the Department determines that such points are more representative of treated (disinfected) water quality within the distribution system. Heterotrophic bacteria, measured as heterotrophic plate count (HPC) as specified in part (10)(a)4 of Rule 0400-45-01-.14, may be measured in lieu of residual disinfectant concentration.

1. Turbidity as required by paragraph (4) of this rule must be continuously measured and recorded on representative samples of the system's combined filtered water while the system serves water to the public. The highest turbidity value obtained during each four-hour period must be reported. A public water system may substitute grab sample monitoring if approved by the Department. For any system using slow sand filtration or filtration treatment other than conventional treatment, direct filtration, or diatomaceous earth filtration, the Department may reduce the sampling frequency to once per day if it determines that less frequent monitoring is sufficient to indicate effective filtration performance. For systems serving 500 or fewer persons, the Department may reduce the turbidity sampling frequency to once per day, regardless of the type of filtration treatment used, if the Department determines that less frequent monitoring is sufficient to indicate effective filtration performance. The highest turbidity measured each four hours must be reported according to the following four hour segments: 12:01 a.m. to 4:00 a.m., 4:01 to 8:00 a.m., 8:01 to 12 noon, 12:01 to 4:00 p.m., 4:01 p.m. to 8:00 p.m., 8:01 to 12 midnight. The intake of the combined filter effluent turbidity monitor shall be located at or near the entry point to the clearwell or at a location approved by the Department.

(Rule 0400-45-01-.31, continued)

2. The residual disinfectant concentration of the water entering the distribution system must be monitored continuously, and the lowest value must be recorded each day. If there is a failure in the continuous monitoring equipment, grab sampling every 4 hours may be conducted in lieu of continuous monitoring, but for no more than 5 working days following the failure of the equipment. Systems serving 3,300 or fewer persons may take grab samples each day in lieu of providing continuous monitoring on an ongoing basis at the frequencies prescribed below:

System Size by Population	Samples/ day[1]
≤500	1
501 to 1,000	2
1,001 to 2,500	3
2,501 to 3,300	4

[1]The day's samples cannot be taken at the same time. The sampling intervals are subject to Department review and approval.

If at any time the free residual disinfectant concentration falls below 0.2 mg/l in a system using grab sampling in lieu of continuous monitoring, the system must take a grab sample every 4 hours until the free residual disinfectant concentration is equal to or greater than 0.2 mg/l.

3. The residual disinfectant concentration must be measured at least at the same points in the distribution system and at the same time as total coliforms are sampled, as specified in paragraph (1) of Rule 0400-45-01-.07. The Department may allow a public water system which uses both a surface water source or a ground water source under direct influence of surface water, and a ground water source to take disinfectant residual samples at points other than the total coliform sampling points if the Department determines that such points are more representative of treated (disinfected) water quality within the distribution system.

4. In addition to monitoring required by parts 1, 2 and 3 of this subparagraph, a subpart H system serving 10,000 or more persons using conventional filtration treatment or direct filtration must conduct continuous monitoring of turbidity for each individual filter using an approved method in subparagraph (10)(b) of Rule 0400-45-01-.14 and must calibrate turbidimeters using the procedure specified in paragraphs (40) and (41) of Rule 0400-45-01-.17. Systems must record the results of individual filter monitoring every 15 minutes. In addition to monitoring required by parts 1, 2 and 3 of this subparagraph by January 14, 2005, a subpart H system serving fewer than 10,000 persons using conventional filtration treatment or direct filtration must conduct continuous monitoring of turbidity for each individual filter using an approved method in subparagraph (10)(b) of Rule 0400-45-01-.14 and must calibrate turbidimeters using the procedure specified in paragraphs (40) and (41) of Rule 0400-45-01-.17. Systems must record the results of individual filter monitoring every 15 minutes.

5. If there is a failure in the continuous turbidity monitoring equipment, the system must conduct grab sampling every four hours in lieu of continuous monitoring until the turbidimeter is repaired and back on-line. A system has a maximum of five working days after failure to repair the equipment or it is in violation.

(6) Reporting and recordkeeping requirements.

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		
MSDS		At least 30 years		29 CFR 1910.1020
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)
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 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) ________________________
b) ________________________
c) ________________________
d) ________________________
e) ________________________
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) ________________________
b) ________________________
c) ________________________
d) ________________________
e) ____

27) Any surface supplied public water system or ground water systems under the direct influence of surface water required to filter shall employ filtration in combination with disinfection that will achieve __________% (_____ log) and __________% (______ log) inactivation of Giardia lamblia and viruses respectively between a point where the raw water is not subject to recontamination by surface water runoff and a point downstream before or at the fist customer.

Rules and Regulation Exercise

Definitions:

1) Public water systems using surface water or ground water under the direct influence of surface water as a source that are subject to the requirements of filtration. 1200-5-1-.04(87)

2) A system for the provision of piped water for human consumption if such serves 15 or more connections or which regularly serves 25 or more individuals daily at least 60 days out of the year. 1200-5-1-.04(75)

MCL's

3)

a) arsenic level at 0.05 mg/L. MCL is 0.05 mg/L until 1/06, then 0.01 mg/L

b) nitrate level at 12 mg/L. MCL is 10 mg/L

c) fluoride level at 4.3 mg/L. MCL 4.0 mg/L

d) atrazine level at 0.005 mg/L. MCL is 0.003 mg/L

e) lindane level at 0.005 mg/L. MCL is 0.0002 mg/L

f) chromium level at 0.4 mg/L. MCL is 0.1 mg/L

(a–f: 1200-5-1-.06 (1)(b) and (2)(a))

g) THM level at 0.09mg/L. MCL is 0.08 mg/L

h) HAA5 level at 0.55 mg/L. MCL is 0.06 mg/L

i) chlorine level at 4.3 mg/L. MCL is 4.0 mg/L

j) chlorine dioxide level at 0.79 mg/L. MCL is 0.8 mg/L

k) chloramine level at 3.9 mg/L. MCL is 4.0 mg/L

(g–k: 1200-5-1-.06 (6)(b) and (6)(c))

l) fecal coliform-positive repeat sample violation

m) E. coli-positive repeat sample violation

n) violation

(l–n: 1200-5-1-.06 (4))

4) 1.0 and 2.0 - Page 16, 1200-5-1-.06(3)

5) a) 40 and 5 , 1200-5-1-.06(4)(a)(1); b) 40 and 1, 1200-5-1-.06(4)(a)(1)

Sampling

6) 30, 1200-5-1-.07(1)(c)

7) 9, 1200-5-1-.07(1)(c)

8) 24, 1, 1, 5, 5; 1200-5-1-.07(2)(a) and (b)

9) 4, 1200-5-1-.08(2)(a)

Operation and Maintenance Requirements

10) surface, filtration, iron, operator, operation; 1200-5-1-.17(1)

11) 10 days; 1200-5-1-.17(2)

12) "Standard Methods for the Examination of Water and Wastewater"; 1200-5-1-.17(3)

13) 0.2 mg/L; 1200-5-1-.17(4)

14) cross-connection, cross-connections; 1200-5-1-.17(6)

15) AWWA standards C-651, C-652 or equivalent methods provided the method has been approved in writing by the department and is available during the inspection, construction, maintenance or repair activity; 1200-5-1-.17(8)(a)

16) 20; 1200-5-1-.17(9)

17) flushing; a) date, b) time, c) location, d) persons responsible, e)length of flushing; 1200-5-1-.17(10)

18) duplicate; 1200-5-1-.17(11)

19) 4.0 gpm per square foot; 1200-5-1-.17(12)(b)

20) a) Dual media: 30 inches, i) Sand: 10-12 inches, ii) Anthracite: 18-20 inches, b) Mixed media beds: 30 inches; 1200-5-1-.17(12)(b) and (d)

21) 24, average daily, 12; 1200-5-1-.17(14)

22) maps; a) water mains, b) sizes of mains, c) valves, d) blow-offs or flush hydrants, e) air-release valves, f) fire hydrants; 1200-5-1-.17(15)

23) wells, storage, tanks, clearwells; 1200-5-1-.17(16)

24) 6, 500, 20; 1200-5-1-.17(18)

25) 0.9, 1.3; 1200-5-1-.17(20)

26) a)name of person with complaint, b) date, c) nature of complaint, d) date of investigation, e)results or actions taken to correct any problems

27) 99.9, 3, 99.99, 4; 1200-5-1-.17(27)(a) and (b)

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**

Section 10

Math

Basic Math Concepts

For Water and Wastewater Plant Operators
by Joanne Kirkpatrick Price

Updated 12-2017

Suggested Strategy

- 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?

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.

$$\frac{3x}{3} = \frac{14}{3}$$

$$x = \frac{14}{3} \qquad x = 4.67$$

- 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.

$$730 = \frac{x}{3847} \times \frac{3847}{1}$$

$$\frac{3847}{1} \times 730 = \frac{x}{3847} \times \frac{3847}{1}$$

$$3847 \times 730 = x$$

$$2{,}808{,}310 = x$$

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. → 46.0%

- To convert from a percent to a decimal
  - Simply move the decimal two points to the left

.79.5% → 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?

$$448 \quad = \quad x\% \quad \times \quad 560$$

$$\frac{448}{560} = \frac{x\% \times \cancel{560}}{\cancel{560}}$$

$$0.80 = x\%$$

$$80\% = x$$

Solving for the Unknown

Basics – finding x

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Finding x^2

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

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

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

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

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

Answers for Solving for the Unknown

Basics – Finding x

1. 1.8
2. 5.7
3. 5.3
4. 5,976,990
5. 8,256.6
6. 8.1
7. 0.005
8. 360
9. 1649.4
10. 244.7
11. 11
12. 5.0
13. 7993.9
14. 590.4
15. 2816.7
16. 4903.5
17. 547,616
18. 117.3
19. 508,000
20. 0.35

Finding x^2

21. 80
22. 12
23. 40
24. 0.83
25. 10.9

Percent Practice Problems

Convert the following fractions to decimals:

1. ¾
2. ⅝
3. ¼
4. ½

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	8.	360	15.	2817
2.	5.7	9.	1649	16.	4903
3.	5.3	10.	244.7	17.	547,616
4.	5,976,990	11.	11	18.	117
5.	8256.6	12.	5	19.	508,000
6.	8.1	13.	7994	20.	0.35
7.	0.005	14.	590.4		

Finding x^2

21.	80	23.	40	25.	10.9
22.	12	24.	0.83		

Percent Practice Problems

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

DIMENSIONAL ANALYSIS

MATHEMATICS MANUAL FOR WATER AND WASTEWATER TREATMENT PLANT OPERATORS
BY FRANK R. SPELLMAN

Updated 12-2017

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

$$\frac{lb}{\cancel{day}} \times \frac{\cancel{day}}{min} =$$

- Units with exponents should be written in expanded form

$$ft^3 = (ft)(ft)(ft)$$

EXAMPLE 1

- Convert 1800 ft^3 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

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

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

Metric Units

Kilo	**Hecto**	**Deca**	**Basic Unit**	**Deci**	**Centi**	**Milli**
King	Henry	Died	By	Drinking	Chocolate	Milk
1000X larger	100X larger	10X larger	Meter Liter Gram ***1 unit***	10X smaller	100X smaller	1000X smaller

→ **MULTIPLY** numbers by 10 if you are getting smaller

← **DIVIDE** number by 10 if you are getting bigger

Problem 1

- Convert 2500 milliliters to liters

Primary Unit

mega	....	kilo	hecto	deka	no	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

- 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

mega	....	kilo	hecto	deka	no	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 me

- 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

CIRCUMFERENCE AND AREA

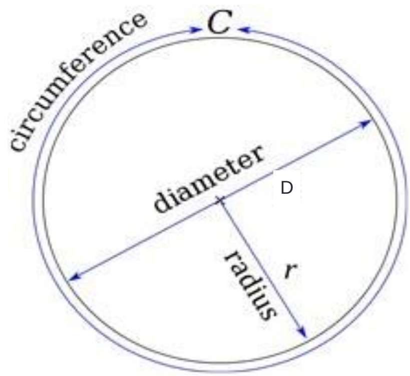
Updated 12-2017

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.

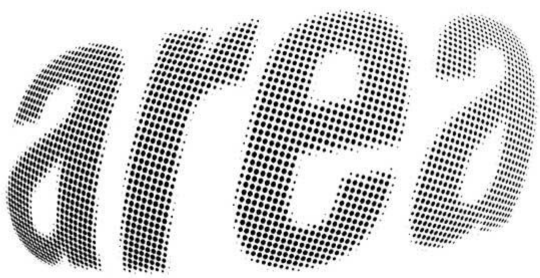
$$Circumference = (3.14)(diameter)$$

$$C = (3.14)(6\ inches)$$

$$C = 18.85\ inches$$

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.

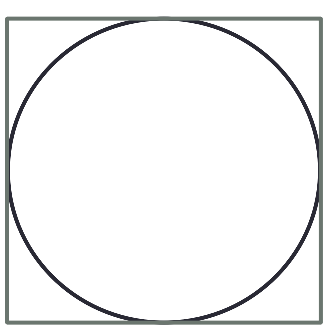


Area

- Area of Circle

$$Area = (0.785)\ (Diameter)^2$$

$$A = (0.785)(D)^2$$



A circle takes up
78.5% of a circle.

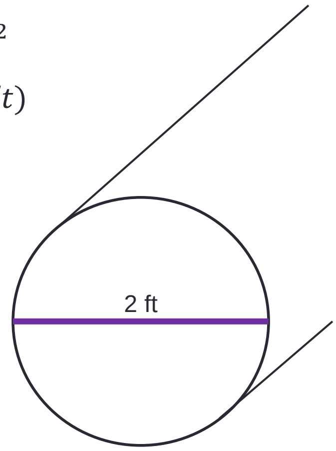
Example 2

- Find the area of the cross section of a pipe in ft^2 that has a diameter of 2 feet.

$$Area = (0.785)(D)^2$$

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

$$A = 3.14\ ft^2$$

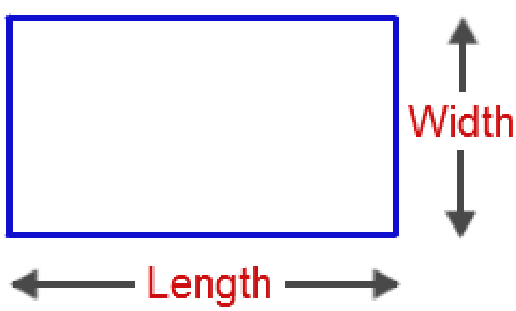


Area

- Area of Rectangle

$$Area = (length)(width)$$

$$A = (L)(W)$$



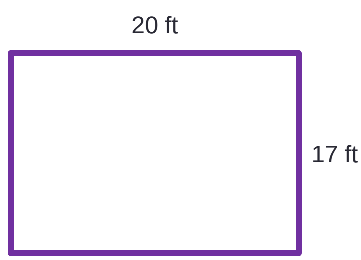
Example 2

- Find the area in ft^2 of a rectangular basin that is 20 feet long and 17 feet wide.

$$A = (L)(W)$$

$$A = (20ft)(17ft)$$

$$A = 340ft^2$$

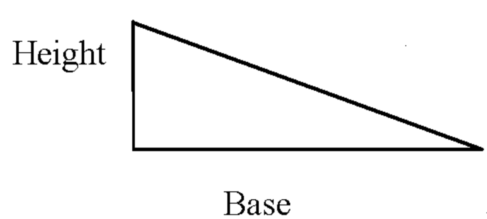


Area

- Area of Right Triangle

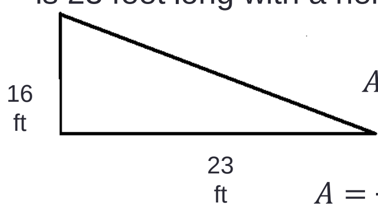
$$Area = \frac{(base)(height)}{2}$$

$$A = \frac{(b)(h)}{2}$$



Example 3

- Determine the area in ft^2 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

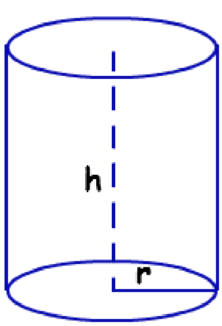
Volume

- 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 1

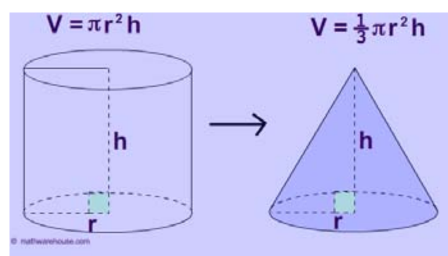
- Determine the volume in ft^3 for a tank that is 20 feet tall with a diameter of 7.5 ft.

$$Vol = (0.785)(D)^2(h)$$

$$Vol = (0.785)(7.5ft)(7.5ft)(20ft)$$

$$Vol = 883.13\ ft^3$$

Volume of a Cone



$$Volume = (1/3)(0.785)(Diameter^2)(height)$$

$$Vol = (1/3)(0.785)(D^2)(h)$$

Example 2

- Determine the volume in gallons of a conical tank that is 8 feet wide and 15 feet tall.

$$Vol = (1/3)(0.785)(D^2)(h)$$

$$Vol = (1/3)(0.785)(8ft)(8ft)(15ft)$$

$$Vol = (0.3333)(753.6\ ft^3)$$

$$Vol = 251.1749\ ft^3$$

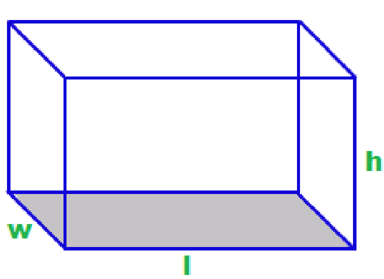
$$Vol, gal = (251.1749\ \cancel{ft}^3)(7.48\ \frac{gal}{\cancel{ft}^3})$$

$$Vol, gal = 1878.78\ gallons$$

Volume of a Rectangle

$$Volume = (length)(width)(height)$$

$$Vol = (l)(w)(h)$$



Example 3

- Determine the volume in m^3 for a tank that measures 30 meters by 15 meters by 25 meters.

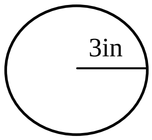
$$Vol = (l)(w)(h)$$

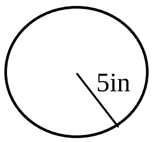
$$Vol = (30m)(15m)(25m)$$

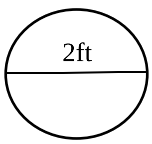
$$Vol = 11{,}250\ m^3$$

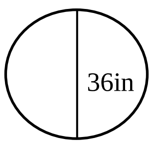
Basic Math for Water and Wastewater
CIRCUMFERENCE, AREA, AND VOLUME

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

1. 18.85 in
2. 31.42 in
3. 6.28 ft
4. 113.10 in
5. 75.40 ft
6. 150.80 in
7. 100.53 ft

Area

1. 540 ft^2
2. 0.55 ft^2
3. 2250 ft^2
4. 3.14 ft^2
5. 27 ft^2
6. 1.77 ft^2

Volume

1. 1000 ft^3
2. 9050.8 gal
3. 359.04 gal
4. 678.58 ft^3
5. 48442.35 gal
6. 150,000 gal
7. 446671.14 gal
8. No, it quadruples it (4X)

Velocity & Flow

Updated 12-2017

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.

$$D = (6\ in)\left(\frac{1\ ft}{12\ in}\right)$$

$$D = 0.5\ ft$$

$$Q = AV$$

$$Q = (0.785)(D^2)\ (vel)$$

$$Q = (0.785)(0.5\ ft)(0.5\ ft)\left(4.5\ {}^{ft}/_{sec}\right)$$

$$Q = 0.88\ {}^{ft^3}/_{sec}$$

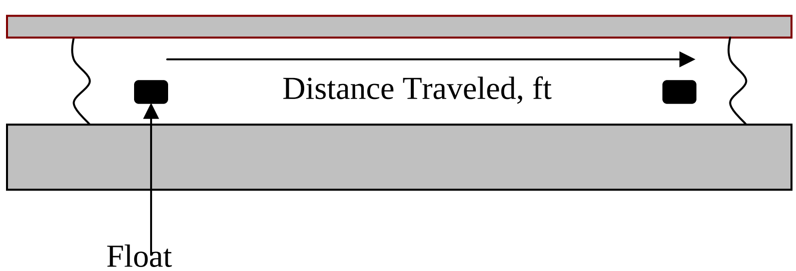
Basic Math for Water and Wastewater
Flow and Velocity

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?

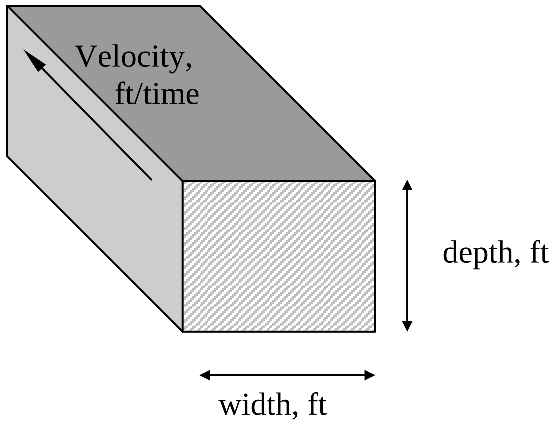
3. The distance between manhole #1 and manhole #2 is 105 feet. A fishing bobber is dropped into manhole #1 and enters manhole #2 in 30 seconds. What is the velocity of the wastewater in the sewer in ft/min?



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

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

1.) 185 ft/min 2.) 2.2 ft/sec 3.) 210 ft/min



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

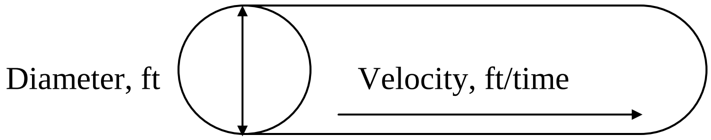
<u>Flow in a channel</u>

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



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

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

Flow through a full pipe

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

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?

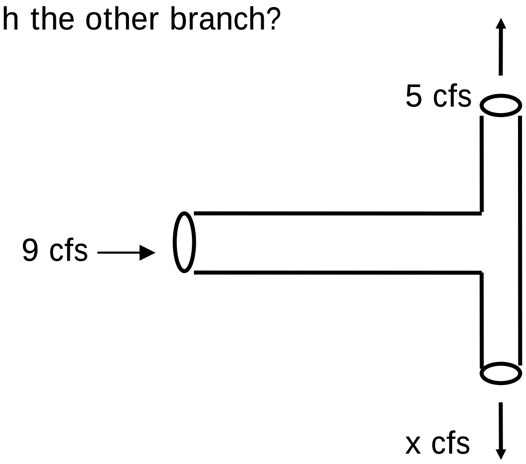
9. A float is placed in a channel. It takes 2.5 minutes to travel 300 feet. What is the velocity in feet per minute in the channel? (Assume that float is traveling at the average velocity of the water.)

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

Disinfection

Chlorination

- The pounds formula will be one of the most important formulas to learn this week.

$$feed\ rate, \frac{lb}{day} = \frac{(dose)(flow)(8.34\frac{lb}{gal})}{\%\ purity}$$

- If no purity provided, assume it is 100%

Example 1

- A water plant that treats 3,200,000 gallons per day. If the required dosage is 5.4 mg/L of 12.5 % sodium hypochlorite, what is the feed rate in lb/day?

$$feed\ rate, \frac{lb}{day} = \frac{(dose)(flow)(8.34\frac{lb}{gal})}{\%\ purity}$$

CT Calculation

Kill = C x T

- Concentration and contact time are two of the most important parameters in chlorination
- They are inversely proportional
  - As one decreases, the other must increase
- CT is simply the concentration of chlorine in your water times the time of contact that the chlorine has with your water
  - Measured in $\frac{mg \cdot min}{L}$

$$CT = (disinfectant\ residual, \frac{mg}{L})(time, min)$$

Example 3

- Treated water is dosed with 5 mg/L of chlorine for 30 minutes. What is the CT?

$$CT = (disinfectant\ residual, \frac{mg}{L})(time, min)$$

Hypochlorite

- 2 types of hypochlorite used for disinfection in typical drinking water systems
  - Sodium hypochlorite
    - NaOCl
    - Bleach
    - 5-15% concentration
  - Calcium hypochlorite
    - $Ca(OCl)_2$
    - High test hypochlorite (HTH)
    - 65% concentration

Hypochlorite Strength

$$Hypochlorite\ strength, \% = \frac{chlorine\ required, lbs}{(hypochlorite\ solution\ needed, gal)(8.34\frac{lb}{gal})} x100$$

- To be used when using bleach in the place of chlorine gas
- Can be used for HTH
  - Just drop the 8.34 conversion

Example 4

- A water plant is switching from chlorine gas to sodium hypochlorite. If 133 lbs of gas was fed each day and they now feed 130 gallons of bleach, what concentration of NaOCl is being used?

$$\%\ strength = \frac{chlorine\ required, lbs}{(hypochlorite\ solution\ needed, gal)(8.34\frac{lb}{gal})} x100$$

Two Normal equation

- C =concentration
- $V = volume\ or\ flow$

$$C_1 \times V_1 = C_2 \times V_2$$

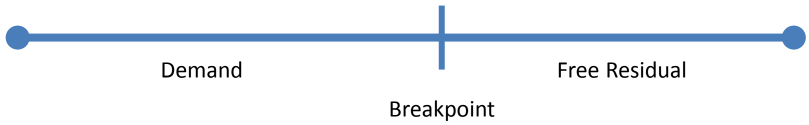
$$want = \ have$$

Example 5

- A distribution operator needs to make 10 gallons of a bleach dilution with a concentration 25 mg/L. The bleach on hand has a concentration of 100 mg/L. How many gallons of the concentrate must be used to achieve the dilution?

$$C_1 \times V_1 = C_2 \times V_2$$

Breakpoint Chlorination



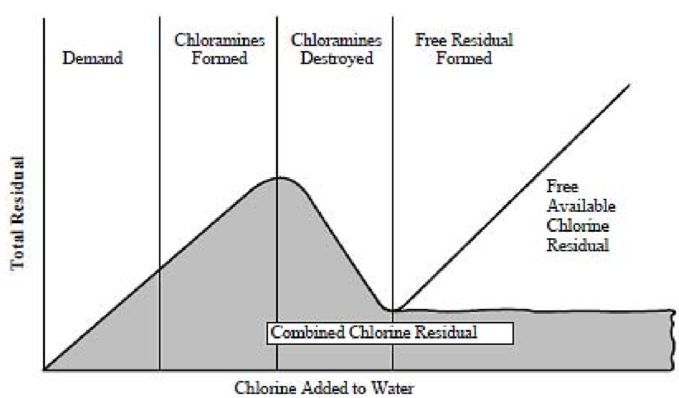
- Total chlorine dose = residual + demand

  -residual - residual

- Dose – residual = demand

Breakpoint Chlorination

- Total chlorine = free residual + combined residual



Applied Math for Water Treatment
Disinfection

1. Determine the chlorinator setting in lb/day required to treat a flow of 3.5 MGD with a chlorine dose of 1.8 mg/L.

2. A flow totalizer reading at 9 am on Thursday was 18,815,108 and at 9 am on Friday was 19,222,420 gallons. If the chlorinator setting is 16 lb for this 24 hour period, what is the chlorine dosage in mg/L?

3. Water from a well is disinfected by a hypochlorinator. The flow totalizer indicates that 2,330,000 gallons of water were pumped during a 7 day period. The 3% sodium hypochlorite solution used to treat the well water is pumped from a 3-foot diameter storage tank. During the 7 day period, the level in the tank dropped 2 ft 10 inches. What is the chlorine dosage in mg/L?

4. A storage tank is to be disinfected with 60 mg/L of chlorine. If the tank holds 86,000 gallons, how many lb of chlorine (gas) will be needed?

5. The chlorine demand of a water process is 1.6 mg/L. If the desired chlorine residual is 0.5 mg/L, what is the desired chlorine dose (in mg/L)?

6. How many pounds of 65% available HTH is needed to make 5 gallons of 18% solution?

7. How many lb of chloride of lime (25% available chlorine) will be required to disinfect a well if the casing is 18 inches in diameter and 200 ft long with the water level 95 ft from the top of the well? The desired chlorine dosage is 100 mg/L

8. A chlorinator setting is 43 lb per 24 hours. If the flow being treated is 3.35 MGD, what is the chlorine dosage expressed as mg/L?

9. The chlorine dosage at a plant is 5.2 mg/L. If the flow rate is 6,250,000 gpd, what is the chlorine feed rate (in lb/day)?

10. A sodium hypochlorite solution (3% available chlorine) is used to disinfect water pumped from a well. A chlorine dose of 2.9 mg/L is required for adequate disinfection. How many gallons per day of sodium hypochlorite will be required if the flow being chlorinated is 955,000 gpd?

11. A flow of 3,021,000 gpd is disinfected with calcium hypochlorite (65% available chlorine). If 49 lb of hypochlorite are used in a 24-hour period, what is the chlorine dosage (in mg/L)?

12. A storage tank that is going to be put back into service requires disinfection at a dosage of 30 mg/L. If the tank has a diameter of 102 ft and is 28.1 ft in height at the overflow, how many gallons of 10.25% sodium hypochlorite solution will be needed if the tank is filled to 10% capacity?

13. The chlorine dosage for a water process is 2.9 mg/L. If the chlorine residual after 30 minutes of contact time is found to be 0.7 mg/L, what is the chlorine demand expressed in mg/L?

14. How many pounds of HTH (65% available chlorine) will it take to make a 2% solution when dissolved in enough water to make 15 gallons of hypochlorite?

15. A chlorine dose of 42 lb/day is required to disinfect a flow of 2,220,000 gpd. If the calcium hypochlorite to be used contains 65% available chlorine, how many mg/L hypochlorite will be required?

16. Determine the chlorinator setting (lb/day) required to treat a flow of 5.5 MGD with a chlorine dose of 2.5 mg/L.

17. Hypochlorite is used to disinfect water pumped from a well. The hypochlorite solution contains 3% available chlorine. A chlorine dose of 2.2 mg/L is required for adequate disinfection throughout the distribution system. If the flow from the well is 245,000 gpd, how much sodium hypochlorite (gallons per day) will be required?

18. A total chlorine dosage of 10 mg/L is required to treat the water in a unit process. If the flow is 1.8 MGD and the hypochlorite has 65% available chlorine, how many lb/day of hypochlorite will be required?

19. Determine the chlorinator setting (lb/day) needed to treat a flow of 980,000 gpd with a chlorine dose of 2.3 mg/L.

20. A water flow of 928,000 gpd requires a chlorine dose of 2.7 mg/L. If calcium hypochlorite (65% available chlorine) is to be used, how many lb/day of hypochlorite are required?

21. A chlorine dose of 2.7 mg/L is required for adequate disinfection of a water unit. If a flow of 810,000 gpd will be treated, how many gallons per day of sodium hypochlorite will be required? The sodium hypochlorite contains 12% available chlorine.

22. A new well is to be disinfected with chlorine at a dosage of 40 mg/L. If the well casing diameter is 6 inches and the length of the water-filled casing is 140 ft, how may lb of chlorine will be required?

23. A flow of 1.34 MGD is to receive a chlorine dose of 2.5 mg/L. What should be the chlorinator setting in lb/day?

24. What should the chlorinator setting be (in lb/day) to treat a flow of 4.8 MGD if the chlorine demand is 8.8 mg/L and a chlorine residual of 3 mg/L is desired?

25. A flow of 3,880,000 gpd is to be disinfected with chlorine. If the chlorine demand is 2.6 mg/L and a chlorine residual of 0.8 mg/L is desired, what should be the chlorinator setting lb/day?

26. The water-filled casing of a well has a volume of 540 gallons. If 0.48 lb of chlorine were used in disinfection, what was the chlorine dosage in mg/L?

27. A hypochlorite solution (4% available chlorine) is used to disinfect a water unit. A chlorine dose of 1.8 mg/L is desired to maintain an adequate chlorine residual. If the flow being treated is 400 gpm, what hypochlorite solution flow (in gallons per day) will be required?

28. A total of 54 lb of hypochlorite (65% available chlorine) is used in a day. If the flow rate treated is 1,512,000 gpd, what is the chlorine dosage (in mg/L)?

29. A flow of 0.83 MGD requires a chlorine dosage of 8 mg/L. If the hypochlorite has 65% available chlorine, how many lb/day of hypochlorite will be required?

30. A total of 36 lb/day sodium hypochlorite is required for disinfection of a flow of 1.7 MGD. How many gallons per day sodium hypochlorite is this?

31. A new well with a casing diameter of 12 inches is to be disinfected. The desired chlorine dosage is 40 mg/L. If the casing is 190 ft long and the water level in the well is 81 feet from the top of the well, how many lb of chlorine will be required?

32. A chlorine dose of 42 mg/L is required to disinfect a flow of 2.22 MGD. If the calcium hypochlorite to be used contains 65% available chlorine, how many lb/day hypochlorite will be required?

33. The chlorine demand of a water unit is 1.8 mg/L. If the desired chlorine residual is 0.9 mg/L, what is the desired chlorine dose (in mg/L)?

34. A total of 51 lb/day sodium hypochlorite is required for disinfection of a flow of 2.28 MGD. How many gallons per day sodium hypochlorite is this?

35. The chlorine dosage for a water unit is 3.1 mg/L. If the chlorine residual after 30 minutes of contact time is found to be 0.6 mg/L, what is the chlorine demand expressed in mg/L?

36. What chlorinator setting (in lb/day) is required to treat a flow of 1620 gpm with a chlorine dose of 2.8 mg/L?

37. A chlorine dose of 2.8 mg/L is required for adequate disinfection of a water unit. If a flow of 1.33 MGD will be treated, how many gpd of sodium hypochlorite will be required? The sodium hypochlorite contains 12.5% available chlorine.

38. A pipeline 8 inches in diameter and 1600 ft long is to be treated with a chlorine dose of 60 mg/L. How many lb of chlorine will this require?

39. The average calcium hypochlorite use at a plant is 34 lb/day. If the chemical inventory in stock is 310 lb, how many days' supply is this?

40. The flow totalizer reading at 7 a.m. on Wednesday was 43,200,000 gallons and at 7 a.m. on Thursday was 44,115,670 gallons. If the chlorinator setting is 18 lb for this 24-hour period, what is the chlorine dosage (in mg/L)?

41. A chlorine dose of 32 mg/L is required to disinfect a flow of 1,990,000 gpd. If the calcium hypochlorite to be used contains 60% available chlorine, how many lb/day hypochlorite will be required?

42. Water from a well is disinfected by a hypochlorinator. The flow totalizer indicates that 2,666,000 gallons of water were pumped during a 7-day period. The 2% sodium hypochlorite solution used to treat the well water is pumped from a 4-foot-diameter storage tank. During the 7-day period, the level in the tank dropped 3 ft 4 inches. What is the chlorine dosage (in mg/L)?

43. A flow of 3,350,000 gpd is to be disinfected with chlorine. If the chlorine demand is 2.5 mg/L and a chlorine residual of 0.5 mg/L is desired, what should be the chlorinator setting (in lb/day)?

44. A total of 72 lb of hypochlorite (65% available chlorine) is used in a day. If the flow rate treated is 1,885,000 gpd, what is the chlorine dosage (in mg/L)?

45. How many lb of dry hypochlorite (65% available chlorine) must be added to 80 gallons of water to make a 2% chlorine solution?

46. An average of 32 lb of chlorine is used each day at a plant. How many lb of chlorine would be used in a week if the hour meter on the pump registers 140 hours of operation that week?

47. An average of 50 lb of chlorine is used each day at a plant. How many 150-lb chlorine cylinders will be required each month? Assume a 30-day month.

Answers

1. 52.54 lb/day
2. 4.7 mg/L
3. 1.93 mg/L
4. 43.03 lb
5. 2.1 mg/L
6. 11.55 lbs
7. 4.67 lb
8. 1.53 mg/L
9. 271.05 lb/day
10. 92.32 gal/day
11. 1.26 mg/L
12. 50.24 gal
13. 2.2 mg/L
14. 3.84 lb
15. 1.47 mg/L
16. 114.68 lb/day
17. 17.97 gal/day
18. 230.95 lb/day
19. 18.80 lb/day
20. 32.3 lb/day
21. 18.23 gal/day
22. 0.07 lb
23. 27.94 lb/day
24. 472.38 lb/day
25. 110.02 lb/day
26. 106.58 mg/L
27. 25.92 gal/day
28. 2.78 mg/L
29. 85.20 lb/day
30. 4.32 gal/day
31. 0.21 lb
32. 1,196.34 lb/day
33. 2.7 mg/L
34. 6.12 gal/day
35. 2.5 mg/L
36. 54.48 lb/day
37. 248.47 lb/day
38. 2.09 lb
39. 9.12 days
40. 2.36 mg/L
41. 885.15 lb/day
42. 2.35 mg/L
43. 83.82 lb/day
44. 2.98 mg/L
45. 20.53 lb
46. 186.67 lb/week
47. 10 cyl/month

Sedimentation

Sedimentation

- Sedimentation is the separation of solids and liquids by gravity
- Calculating volume must be done based on the shape of the tank
  - Typically rectangular or cylindrical
- Detention time is the amount of time the water is supposed to spend in the tank

Volume

- Cylindrical tank

$$volume, ft^3 = (0.785)(D^2)(h)$$

- Rectangular tank

$$volume, ft^3 = (l)(w)(d)$$

Detention Time

$$detention\ time = \frac{volume}{flow}$$

- Units must be compatible within the equation

Example 1

- A sedimentation tank has a volume of 137,000 gallons. If the flow to the tank is 121,000 gph, what is the detention time in the tank (in hours)?

$$detention\ time = \frac{volume}{flow}$$

$$DT = \frac{137{,}000\ gal}{121{,}000\frac{gal}{hr}}$$

$$DT = 1.13\ hours$$

Surface Overflow Rate

- Hydraulic loading rate (HLR) is used to determine loading on sedimentation basins and circular clarifiers
  - Measures the total water entering the process

$$HLR = \frac{total\ flow\ applied, gpd}{area, ft^2}$$

- Surface overflow rate (SOR) measures only the water overflowing the process

$$SOR = \frac{flow, gpd}{area, ft^2}$$

Example 2

- A circular clarifier has a diameter of 80 ft. If the flow to the clarifier is 2.6 MGD, what is the surface overflow rate in gpm/sq.ft?

$A = (0.785)(D^2)$

$$SOR = \frac{flow, gpd}{area, ft^2}$$

$$SOR = \frac{2{,}600{,}000\ gpd}{(0.785)(80ft)(80ft)}$$

$$SOR = \frac{2{,}600{,}000\ gpd}{5024\ ft^2}$$

$$SOR = 517.51\ \frac{gpd}{ft^2}$$

Weir Overflow Rate

- Weir overflow rate (WOR) is the amount of water leaving the settling tank per linear foot of weir
- Calculation result can then be compared to design
- Mesaured in gpd/ft

$$WOR = \frac{flow, gpd}{weir\ length, ft}$$

Example 3

- A circular clarifier receives a flow of 3.55 MGD. If the diameter of the weir is 90 ft, what is the weir overflow rate in gpd/ft?

$$circumference = \pi * Diameter$$
$$Circ = (\pi)(90ft)$$
$$Circ = 282.7433\ ft$$

$$WOR = \frac{flow, gpd}{weir\ length, ft}$$

$$WOR = \frac{3{,}550{,}000\ gpd}{282.7433\ ft}$$

$$WOR = 12555.56\ \frac{gpd}{ft}$$

Reduction in Flow

- To determine the reduction in flow after a period of time

$$Reduction\ in\ flow, \% = \left(\frac{original\ flow - reduced\ flow}{original\ flow}\right) \times 100$$

Example 4

- A sedimentation tank was designed to produce 500,000 gpd at start up. After 5 years in operation, the tank produces 425,000 gpd. What is the reduction in flow?

$$Reduction\ in\ flow, \% = \left(\frac{original\ flow - reduced\ flow}{original\ flow}\right) \times 100$$

$$Reduction = \left(\frac{500{,}000\ gpd\ - 425{,}000\ gpd}{500{,}000\ gpd}\right) \times 100$$

$$Reduction = \left(\frac{75{,}000\ gpd}{500{,}000\ gpd}\right) \times 100$$

$$Reduction = 15\%$$

Solids

- Total suspended solids are the amount of filterable solids in a water sample
  - Weigh dried filter
- Settleable solids will settle out due to gravity
  - Imhoff cone
- Dissolved solids are the amount of solids that pass through a filter in a water sample
  - Weigh filtered water

Solids Concentration

$$Solids\ concentration, \frac{mg}{L} = \frac{weight, mg}{volume, L}$$

$$Solids, \frac{mg}{L} = \frac{(dry\ solids, grams)(1{,}000{,}000)}{sample\ volume, mL}$$

Settleable Solids

- The settleable solids test is an easy, quantitative method to measure sediment found in water
- An Imhoff cone is filled with 1 liter of sample, stirred and allowed to settle for 60 minutes

$$Removal, \% = \left(\frac{in - out}{in}\right) \times 100$$

Example 6

- Calculate the percent removal of settleable solids if the settleable solids of the sedimentation tank influent is 13 mL/L and the settleable solids of the effluent is 0.5 mL/L.

$$Removal, \% = \left(\frac{in - out}{in}\right) \times 100$$

$$Removal = \left(\frac{13\frac{mL}{L} - 0.5\frac{mL}{L}}{13\frac{mL}{L}}\right) \times 100$$

$$Removal = \left(\frac{12.5\frac{mL}{L}}{13\frac{mL}{L}}\right) \times 100$$

$$Removal = 0.96 \times 100$$

$$Removal = 96\%$$

Small Water Systems
Sedimentation

1. Calculate the percent removal of settleable solids if the settleable solids of the sedimentation tank influent are 21.2 mL/L and the settleable solids of the effluent are 1.3 mL/L.

2. A sedimentation basin is 70 ft long by 30 ft wide. If the water depth is 14 ft, what is the volume of water in the tank in gallons?

3. A rectangular sedimentation basin is 70 ft long 25 ft wide and has water to a depth of 10 ft. The flow to the basin is 2,220,000 gpd. Calculate the detention time in hours for the sedimentation basin.

4. A rectangular sedimentation basin is 60 ft long and 25 ft wide. When the flow is 510 gpm, what is the surface overflow rate in gpm/ft^2?

5. A 22 ac pond receives a flow of 3.6 ac-ft per day. What is the hydraulic loading rate in gpd/ft^2?

6. A circular clarifier receives a flow of 2,520,000 gpd. If the diameter of the weir is 70 ft, what is the weir overflow rate (in gpd/ft)?

7. A tank is 30 ft wide and 80 ft long. If the tank contains water to a depth of 12 ft, how many gallons of water are in the tank?

8. The flow to a sedimentation tank that is 80 ft long, 20 ft wide, and 12 ft deep is 1.8 MGD. What is the detention time in the tank (in hours)?

9. A rectangular clarifier receives a flow of 5.4 MGD. The length of the clarifier is 99 feet 7 inches and the width is 78 feet 6 inches. What is the SOR in gpd/ft^2?

10. The weir in a basin measures 30 feet by 15 feet. What is the weir overflow rate (gpd/ft) when the flow is 1,098,000 gpd?

11. A flash mix chamber is 6 ft long, 5 ft wide, and 5 ft deep. It receives a flow of 9 MGD. What is the detention time in the chamber in seconds?

12. A sedimentation basin is 80 ft long and 25 ft wide. To maintain a surface overflow rate of 0.5 gallons per day per square foot, what is the maximum flow to the basin in gallons per day?

13. A circular clarifier receives a flow of 2.12 MGD. If the diameter of the weir is 60 ft, what is the weir overflow rate (in gpd/ft)?

14. A flocculation basin is 8 ft deep, 16 ft wide, and 30 ft long. If the flow through the basin is 1.45 MGD, what is the detention time (in minutes)?

15. A flash mix chamber is 4 ft square and has a water depth of 42 inches. If the flash mix chamber receives a flow of 3.25 MGD, what is the detention time (in seconds)?

16. A sedimentation tank has a total of 150 feet of weir over which the water flows. What is the weir overflow rate in gallons per day per foot of weir when the flow is 1.7 MGD?

17. A sedimentation tank is 90 feet long and 40 feet wide and receives a flow of 5.04 MGD. Calculate the SOR in gpd/ft^2.

18. A tank has a length of 100 feet, a width of 25 feet and a depth of 15 feet. What is the area of the water's surface in ft^2?

19. What is the gpd/ft^2 overflow to a circular clarifier that has the following:
Diameter: 70 feet
Flow: 1,950 gpm

20. The flow to a sedimentation tank that is 75 ft long, 30 ft wide, and 14 ft deep is 1,640,000 gpd. What is the detention time in the tank (in hours)?

21. A sedimentation tank 70 ft by 25 ft receives a flow of 2.05 MGD. What is the surface overflow rate (in gpd/sq ft)?

22. A flocculation basin is 50 ft long by 20 ft wide and has a water level of 8 ft. What is the detention time (in minutes) in the basin if the flow to the basin is 2.8 MGD?

23. The diameter of a tank is 90 ft. If the water depth in the tank is 25 ft, what is the volume of water in the tank (in gallons)?

24. A backwash lagoon receives a flow of 18,800 gpd. If the surface area of the pond is 16 acres, what is the hydraulic loading rate in gpd/ft^2?

25. The average width of a pond is 400 ft and the average length is 440 ft. The depth is 6 ft. If the flow to the pond is 200,000 gpd, what is the detention time (in days)?

26. A rectangular sedimentation basin has a total of 170 ft of weir. If the flow to the basin is 1,890,000 gpd, what is the weir overflow rate in gpd/ft^2?

27. A clarifier has a diameter of 82 feet and a depth of 12 feet. What is the length of the weir around the clarifier in ft?

28. The diameter of the weir in a circular clarifier is 125 feet. The flow is 6.33 MGD. What is the weir overflow rate (gpd/ft)?

29. A clarifier has a diameter of 82 feet and a depth of 12 feet. What is the surface area of the clarifier in ft^2?

30. A clarifier has a flow rate of 4,600 gpm and a diameter of 75 feet. What is the surface overflow rate in gpd/ft^2?

31. The flow rate to a particular clarifier is 528 gpm and the tank has a length of 30 feet and a width of 17.5 feet. What is the gpd/ft of weir?

32. Calculate the percent removal of settleable solids if the settleable solids of the sedimentation tank influent are 13.9 mL/L and the settleable solids of the effluent are 0.7 mL/L.

33. The flow to a flocculation basin is 6,625,000 gpd. If the basin is 60 ft long, 25 ft wide, 15 ft deep, and contains water to a depth 9 ft, what is the detention time of the flocculation basin in minutes?

34. A circular clarifier has a diameter of 70 ft. If the flow to the clarifier is 1610 gpm, what is the surface overflow rate in gpm/ft^2?

35. A waste treatment pond is operated at a depth of 6 ft. The average width of the pond is 500 ft and the average length is 600 ft. If the flow to the pond is 222,500 gpd, what is the detention time (in days)?

36. A sedimentation tank has a total of 200 feet of weir which the water flows over. What is the weir overflow rate (gpd/ft) when the flow is 2.2 MGD?

37. A tank has a length of 100 feet, a width of 25 feet, and a depth of 15 feet. What is the weir length around the basin in feet?

38. The flow to a sedimentation tank is 3.05 MGD. If the tank is 80 feet long and 20 feet wide, what is the surface overflow rate in gallons per day per square foot?

39. What is the weir overflow rate of a clarifier that is 50 feet 4 inches by 44 feet 3 inches and has an influent flow of 1.87 MGD?

40. The flow through a flocculation basin is 1.82 MGD. If the basin is 40 ft long, 20 ft wide, and 10 ft deep, what is the detention time (in minutes)?

41. A tank is 80 ft long, 20 ft wide, and 16 ft deep. What is the volume of the tank (in cubic feet)?

42. The flow to a circular clarifier is 2.66 MGD. If the diameter of the clarifier is 70 ft, what is the surface overflow rate (in gpd/sq ft)?

43. The flow rate to a clarifier is 1400 gpm. If the diameter of the weir is 80 ft, what is the weir overflow rate (in gpd/ft)?

44. A clarifier with a diameter of 55 feet receives a flow of 2.075 MGD. What is the surface overflow rate (gpd/ft^2)?

45. A circular clarifier has a diameter of 60 ft and an average water depth of 12 ft. What flow rate (MGD) corresponds to a detention time of 3 hours?

46. A circular clarifier has a diameter of 80 feet. If the water depth is 12 ft, how many gallons of water are in the tank?

47. A basin 3 ft by 4 ft is to be filled to the 3-ft level. If the flow to the tank is 6 gpm, how long will it take to fill the tank (in hours)?

48. The diameter of the weir in a circular clarifier is 85 feet. What is the weir overflow rate (gpd/ft) if the flow over the weir is 2.24 MGD?

49. A sedimentation tank is 110 ft long and 50 ft wide. If the flow to the tank is 3.45 MGD what is the surface overflow rate (in gpd/sq ft)?

50. A tank 6 ft in diameter is to be filled to the 4-ft level. If the flow to the tank is 12 gpm, how long will it take to fill the tank (in minutes)?

51. A rectangular clarifier has a total of 163 ft of weir. What is the weir overflow rate (in gpd/ft) when the flow is 1,410,000 gpd?

52. A circular clarifier has a diameter of 80 feet. If the flow to the clarifier is 3.8 MGD, what is the surface overflow rate (gpd/ft^2)?

53. The diameter of the weir in a circular clarifier is 85 feet. What is the weir overflow rate (gpd/ft) if the flow over the weir is 2.24 MGD?

54. A rectangular clarifier has a total of 240 ft of weir. What is the weir overflow rate (in gpd/ft) when the flow is 2.7 MGD?

55. A tank has a diameter of 49.4 feet. What is the gallons/day per foot of weir overflow when the tank receives 1,953,000 gpd?

56. The flow to a flocculation basin is 3,625,000 gpd. If the basin is 60 ft long by 25 ft wide and contains water to a depth of 9 ft, what is the detention time of the flocculation basin (in minutes)?

57. A flocculation basin is 50 ft long by 20 ft wide and has a water depth of 10 ft. If the flow to the basin is 2,250,000 gpd, what is the detention time (in minutes)?

58. The flow to a sedimentation tank is 50,000 gpd. If the tank is 55 feet long and 15 feet wide, what is the surface overflow rate (gpd/ft^2)?

59. A pre-sedimentation pond receives a flow of 1.2 MGD. This particular pond is 115 ft long, 40 ft wide and averages a depth of 15 ft. Determine the hydraulic loading rate in gpd/ft^2?

60. A circular clarifier has a diameter of 80 ft and an average water depth of 12 ft. If the flow to the clarifier is 2,920,000 gpd, what is the detention time in hours?

61. A rectangular sedimentation basin has a total weir length of 189 ft. If the flow to the basin is 4.01 MGD, what is the weir-loading rate (in gpd/ft)?

62. The flow rate to a circular clarifier is 5.20 MGD. If the clarifier is 80 ft in diameter with water to a depth of 10 ft, what is the detention time (in hours)? 1.7 hr

ANSWERS

1. 93.9%
2. 219,912 gal
3. 1.43 hrs
4. 0.34 gpm/ft^2
5. 1.22 gpd/ ft^2
6. 11,459.16 gpd/ft
7. 215,424 gal
8. 1.91 hrs
9. 690.78 gpd/ ft^2
10. 12,200 gpd/ft
11. 10.77 sec
12. 1000 gpd
13. 11,246.95 gpd/ft
14. 28.51 min
15. 11.13 sec
16. 11,333.33 gpd/ft
17. 1,400 gpd/ ft^2
18. 2,500 ft^2
19. 730.01 gpd/ ft^2
20. 3.45 hr
21. 1,171.43 gpd/ ft^2
22. 30.82 min
23. 1,189,039.5 gal
24. 0.027 gpd/ ft^2
25. 40.39 days
26. 11,117.65 gpd/ft
27. 257.61 ft
28. 80,596.06 gpd/ft
29. 5,278.34 ft^2
30. 1,500.13 gpd/ ft^2
31. 8,003.37 gpd/ft
32. 95%
33. 21.89 min
34. 0.42 gpm/ ft^2
35. 60.5 days
36. 11,000 gpd/ft
37. 250 ft
38. 1,906.25 gpd/ ft^2
39. 9,885.47 gpd/ft
40. 47.38 min
41. 25,600 ft^3
42. 691.54 gpd/ ft^2
43. 8,021.41 gpd/ft
44. 873.82 gpd/ ft^2
45. 2.03 MGD
46. 450,954.24 gal
47. 0.75 hrs
48. 8,388.40 gpd/ft
49. 627.27 gpd/ ft^2
50. 70.46 min
51. 8,650.31 gpd/ft
52. 756.37 gpd/ ft^2
53. 394.95 gpd/ ft^2
54. 11,250 gpd/ft
55. 12,584.19 gpd/ft
56. 40.18 min
57. 47.81 min
58. 60.61 gpd/ ft^2
59. 260.87 gpd/ ft^2
60. 3.71 hr
61. 212,168.93 gpd/ft
62. 1.74 hr

Filtration

Filtration

- Process of separating suspended and colloidal particle waste by passing the water through a granular material
- Involves straining, settling, and adsorption

Filter Flow & Backwash Rate

- Rate at which water flows through the filter
- Can be used to verify flow meter readings

$$\frac{gpm}{ft^2} = \frac{flow, gpm}{filter\ area, ft^2}$$

Example 1

- A filter 18 ft by 22 ft receives a flow of 1750 gpm. What is the filtration rate in gpm/ft^2?

$$\frac{gpm}{ft^2} = \frac{flow, gpm}{filter\ area, ft^2}$$

Example 2

- A filter that is 30 ft by 10ft has a backwash rate of 3120 gpm. What is the back wash rate in gpm/sq. ft?

$$\frac{gpm}{ft^2} = \frac{flow, gpm}{filter\ area, ft^2}$$

Filter Drop Test Velocity

- Speed at which water flows through the filter

$$\frac{ft}{min} = \frac{water\ drop, ft}{time\ of\ drop, min}$$

Example 3

- The influent to a filter is closed while the effluent valve remains open. It is measured that in 1 minute, the water level drops 1.5 feet. What is the filter drop test velocity?

$$\frac{ft}{min} = \frac{water\ drop, ft}{time\ of\ drop, min}$$

Filter Backwash Rise Rate

- Upward velocity of the water during backwashing

$$\frac{in}{min} = \frac{(backwash\ rate, \frac{gpm}{ft^2})(12\frac{in}{ft})}{7.48\frac{gal}{ft^3}}$$

Example 4

- A filter has a backwash rate of 16 gpm/sq. ft. What is the inch per minute backwash rate?

$$\frac{in}{min} = \frac{(backwash\ rate, \frac{gpm}{ft^2})(12\ \frac{in}{ft})}{7.48\,\frac{gal}{ft^3}}$$

Applied Math for Water Treatment
Filtration

1. A filter 40 ft by 20 ft receives a flow of 2230 gpm. What is the filtration rate (in gpm/sq ft)?

2. The influent valve to a filter is closed for a 5-minute period. During this time, the water level in the filter drops 12 inches. If the filter is 45 ft long by 22 ft wide, what is the gpm flow rate through the filter?

3. The influent valve to a filter is closed for 6 minutes. The water level in the filter drops 18 inches during the 6 minutes. If the filter is 35 ft long by 18 ft wide, what is the gpm flow rate through the filter?

4. During an 80 hour filter run, a total of 14.2 million gallons of water are filtered. What is the average gpm flow rate through the filter during this time?

5. A filter 18 ft long by 14 ft wide has a backwash flow rate of 3580 gpm. What is the filter backwash rate (in gallons per minute per square foot)?

6. A backwash flow rate of 6750 gpm for a total of 6 minutes would require how many gallons of water?

7. The desired backwash pumping rate for a filter is 20 gallons per minute per square foot. If the filter is 36 ft long by 26 ft wide, what backwash pumping rate (gallons per minute) will be required?

8. A filter 38 ft long by 22 ft wide receives a flow of 3,550,000 gpd. What is the filtration rate (in gallons per minute per square foot)?

9. A filter 40 ft by 20 ft treats a flow of 2.2 MGD. What is the filtration rate (in gpm/sq ft)?

10. A filter is 40 ft long by 30 ft wide. To verify the flow rate through the filter, the filter influent valve is closed for a 5-minute period and the water drop is measured. If the water level in the filter drops 14 inches during the 5 minutes, what is the gpm flow rate through the filter?

11. A filter has a surface area of 32 ft by 18 ft. If the filter receives a flow a 2,150,000 gpd, what is the filtration rate (in gallons per minute per square foot)?

12. The backwash flow rate for a filter is 3700 gpm. If the filter is 15 ft by 20 ft, what is the backwash rate expressed as gpm/ft^2?

13. A filter is 38 ft long by 18 ft wide. During a test of filter flow rate, the influent valve to the filter is closed for 5 minutes. The water level drops 22 inches during this period. What is the filtration rate for the filter (in gallons per minute per square foot)?

14. A backwash flow rate of 6650 gpm for a total backwashing period of 6 minutes would require how many gallons of water for backwashing?

15. A filter 30 ft by 18 ft has a backwash flow rate of 3650 gpm. What is the filter backwash rate (in gallons per minute per square foot)?

16. The desired backwash pumping rate for a filter is 24 gallons per minute per square foot. If the filter is 26 ft long by 22 ft wide, what backwash pumping rate (gallons per minute) will be required?

17. A filter 14 ft by 14 ft has a backwash flow rate of 4750 gpm. What is the filter backwash rate in gpm/sq ft?

18. A filter with a surface area of 380 square feet has a backwash flow rate of 3510 gpm. What is the filter backwash rate (in gallons per minute per square foot)?

19. A filter 38 ft long by 24 ft wide produces a total of 18.1 million gallons during a 71.6-hour filter run. What is the average filtration rate for this filter run in gpm/ft^2?

20. During an 80-hour filter run, a total of 14.2 million gallons of water are filtered. What is the average gpm flow rate through the filter during this time?

21. A filter 40 ft by 25 ft receives a flow of 3100 gpm. What is the filtration rate (in gpm/sq ft)?

22. A filter 20 ft long by 18 ft wide receives a flow of 1760 gpm. What is the filtration rate (in gallons per minute per square foot)?

23. A filter is 42 ft long by 22 ft wide. If the desired backwash rate is 19 gallons per minute per square foot, what backwash pumping rate (gallons per minute) will be required?

24. For a backwash flow rate of 9100 gpm and a total backwash time of 7 minutes, how many gallons of water will be required for backwashing?

25. A total of 59,200 gallons of water will be required to provide a 7-minute backwash of a filter. What depth of water in feet is required in the backwash water tank to provide this backwashing capability? The tank has a diameter of 40 ft.

26. At an average flow rate through a filter of 3200 gpm, how long a filter run (in hours) would be required to produce 16 million gallons of water?

27. A filter is 33 ft long by 24 ft wide. During a test of flow rate, the influent valve to the filter is closed for 6 minutes. The water level drops 21 inches during this period. What is the filtration rate for the filter (in gallons per minute per square foot)?

28. A backwash rate of 7150 gpm is desired for a total backwash time of 7 minutes. What depth of water in feet is required in the backwash water tank to provide this much water? The diameter of the tank is 40 ft.

29. A filter 25 ft by 15 ft. If the backwash flow rate is 3400 gpm, what is the filter backwash rate (in gpm/sq. ft)?

30. A filter 33 ft long by 24 ft wide produces a total of 14.2 million gallons during a 71.4-hour filter run. What is the average filtration rate for this filter run in gpm/ft^2?

31. A filter has a surface area of 880 sq ft. If the flow treated is 2850 gpm, what is the filtration rate (in sq. ft)?

32. At an average flow rate through a filter of 3200 gpm, how long a filter run (in hours) would be required to produce 16 million gallons of filtered water?

33. A filter 26 ft by 60 ft receives a flow of 2500 gpm. What is the filtration rate (in gpm/sq ft)?

34. A filter 25 ft by 30 ft at a rate of 3300 gpm. What is this backwash rate expressed as gpm/ft^2?

35. The flow rate through a filter is 2.97 MGD. What is the flow rate in gpm?

36. How many gallons of water would be required to provide a backwash flow rate of 4670 gpm for a total of 5 minutes?

37. A filter is 22 ft square. If the desired backwash rate is 16 gallons per minute per square foot, what backwash pumping rate (gallons per minute) will be required?

38. A filter 18 ft long by 14 ft wide has a backwash rate of 3080 gpm. What is this backwash rate expressed in inches minute of water?

39. The Quahog Water Treatment Plant treats an average of 5.18 MGD. The water is split equally to each of the 8 filters. Each filter measures 12 feet wide by 16 feet long and 24 feet deep. The influent to Filter 6 is closed while the effluent remains open to perform a drop test. Using a stop watch and a hook gauge, it is noted that the water level in the filter drops 6 inches in 80 seconds. A hook gauge was used to determine the rate of rise in the filter basin during the backwash cycle. The water rose 6 inches in 15 seconds.

    a. What is the filtration rate in gallons per minute per square foot?

    b. What is the backwash rate in gallons per minute per square foot?

40. The Central City Water Treatment Plant treats an average of 7.2 MGD. The water is split equally to each of the 12 filters. Each filter measures 12.5 feet wide by 16.5 feet long and 24 feet deep. Influent to Filter 6 is closed while the effluent remains open to perform a drop test. Using a stop watch and a hook gauge, it is noted that the water level in the filter drops 6 inches in 75 seconds. A hook gauge was used to determine the rate of rise in the filter basin during the backwash cycle. The water rose 6 inches in 13 seconds.

    a. What is the filtration rate in gallons per minute per square foot?

    b. What is the backwash rate in gallons per minute per square foot?

Answers

1. 2.78 gpm/ft^2
2. 1481.04 gpm
3. 1178.1 gpm
4. 2958.33 gpm
5. 14.21 gpm/ft^2
6. 40,500 gal
7. 18,720 gpm
8. 2.95 gpm/ft^2
9. 1.91 gpm/ft^2
10. 2094.46 gpm
11. 2.59 gpm/ft^2
12. 12.33 gpm/ft^2
13. 2.74 gpm/ft^2
14. 39,900 gal
15. 6.76 gpm/ft^2
16. 13,728 gpm
17. 24.23 gpm/ft^2
18. 9.24 gpm/ft^2
19. 4.62 gpm/ft^2
20. 2958.33 gpm
21. 3.1 gpm/ft^2
22. 4.89 gpm/ft^2
23. 17,556 gpm
24. 63,700 gal
25. 6.3 ft
26. 83.33 hr
27. 2.18 gpm/ft^2
28. 5.33 ft
29. 9.07 gpm/ft^2
30. 4.19 gpm/ft^2
31. 3.24 gpm/ft^2
32. 83.33 hr
33. 1.6 gpm/ft^2
34. 4.4 gpm/ft^2
35. 2061.8 gpm
36. 23,350 gal
37. 7744 gpm
38. 19.61 in/min
39. a. 2.81 gpm/ft^2
    b. 14.96 gpm/ft^2
40. a. 2.99 gpm/ft^2
    b. 17.26 gpm/ft^2

LABORATORY CALCULATIONS

MOLARITY & NORMALITY

AWWA Basic Science Concepts and Applications

TERMS

- Mole - a gram molecular weight; that is, the molecular weight expressed as grams
- Molecular weight - the weight of one molecule
  - Example: NaCl
    - Na weight = 22.9898 g/mol
    - Cl weight = 35.453 g/mole
    - Molecular weight of NaCl = 22.9898 + 35.453 = 58.4428 g/mol

NUMBER OF MOLES

- If 150 g of sodium hydroxide (NaOH) is mixed into water to make a solution, how many moles of solute have been used? (molecular weight of NaOH is 40.00 gram/mol)

$$\#\ of\ moles = \frac{total\ weight}{molecular\ weight}$$

$$\#\ of\ mol = \frac{150\ g}{40.00\ g/mol}$$

$$\#\ of\ mol = 3.75\ mol\ of\ NaOH$$

MOLARITY

- Once the number of moles of solute has been determined, the molarity of a solution may be calculated
  - Molarity is the concentration of a solution

$$Molarity = \frac{moles\ of\ solute}{liters\ of\ solution}$$

$$M = \frac{mol}{L}$$

EXAMPLE 1

- If 0.4 mol of NaOH is dissolved in 2 L of solution, what is the molarity of the solution?

$$Molarity = \frac{moles\ of\ solute}{liters\ of\ solution}$$

$$M = \frac{0.4\ mol}{2\ L}$$

$$M = 0.2\ \mathrm{M}$$

EQUIVALENT WEIGHTS

- The equivalent weight of an element or compound is the weight of that element or compound that in a given reaction has the same combining capacity as 8 grams of oxygen or as 1 gram of hydrogen
- The equivalent weight of a reactant will be *equal* to the reactant's molecular weight

$$milliequivalent = (mL\ of\ sol'n)(normality)$$

EXAMPLE 2
NUMBER OF EQUIVALENT WEIGHTS

- If 90 grams of sodium hydroxide (NaOH) were used in making up a solution, how many equivalent weights were used. Use 40.00 g as the equivalent weight for NaOH.

$$\#\ equivalent\ weights = \frac{total\ weight}{equivalent\ weight}$$

$$\frac{amt.\ used\ in\ sol'n}{weight\ of\ compound}$$

$$\#\ equivalent\ weights = \frac{90\ g}{40\ g}$$

$$\#\ equivalent\ weights = 2.25\ equivalent\ weights$$

NORMALITY

- When you have determined the number of equivalent weights of the dissolved solute, you can determine the normality of the solution
- Normality is a measure of the reacting power of a solution
    - i.e. 1 equivalent of a substance reacts with 1 equivalent of another substance

$$Normality = \frac{\#\ of\ equivalent\ weights\ of\ solute}{liters\ of\ solution}$$

$$N = \frac{equivalents}{L}$$

EXAMPLE 3

- If 2.1 equivalents of NaOH were used in making up 1.75 L of solution, what is the normality of the solution?

$$Normality = \frac{\#\ of\ equivalent\ weights\ of\ solute}{liters\ of\ solution}$$

$$N = \frac{2.1\ equivalents}{1.75\ liters}$$

$$N = 1.2\ N$$

TWO NORMAL EQUATION

- $C = concentration$
- $V = volume\ or\ flow$

$$C_1 \times V_1 = C_2 \times V_2$$

want = have

EXAMPLE 4

- To titrate a sample for alkalinity, 200 mL 0.02 N H_2SO_4 is needed. How much mL of 1.0 N H_2SO_4 is needed to obtain the desired amount and concentration?

$$C_1 \times V_1 = C_2 \times V_2$$

THREE NORMAL EQUATION

- $N = normality$
- $V = volume\ or\ flow$

$$(N_1 \times V_1) + (N_2 \times V_2) = (N_3 \times V_3)$$

Be sure to follow order of operations!

HARDNESS, ALKALINITY

AWWA Basic Science Concepts and Applications

HARDNESS

- Measurement of the effects that water impurities have on corrosion scaling and soap
- Measured in mg/L as $CaCO_3$

$$Hardness = \frac{(Titrant\ volume, mL)(1000)}{sample\ volume, mL}$$

EXAMPLE 5

- If 18 mL of EDTA were used to titrate a sample to the end point of a 100 mL sample, what is the hardness in mg/L as $CaCO_3$?

$$Hardness = \frac{(titrant\ volume, mL)(1000)}{sample\ volume, mL}$$

ALKALINITY

- A measure of the water's ability to resist change to pH
- Measured in mg/L as $CaCO_3$
- Composed of the carbonate, bicarbonate, and hydroxide content of the water

$$Alkalinity = \frac{(titrant\ vol, mL)(acid\ normality)(50{,}000)}{sample\ volume, mL}$$

EXAMPLE 6

- A 100 mL sample was titrated a pH of 8.3 with 9 mL of 0.02N H_2SO_4. What is the alkalinity?

$$alkalinity = \frac{(titrant\ vol., mL)(acid\ normality)(50{,}000)}{sample\ volume, mL}$$

TOTAL AND PHENOLPHTHALEIN ALKALINITY

- Phenolphthalein alkalinity (P) found by titrating sample to pH of 8.3
  - Phenolphthalein powder pillow
- Total alkalinity (T) found by titrating sample to pH of 4.5
  - Bromcresol green – methyl red powder pillow
  - Methyl orange powder pillow
- Alkalinity is composed of the carbonate, bicarbonate, and hydroxide content of the water

ALKALINITY RELATIONSHIPS

Result of Titration	Hydroxide	Carbonate	Bicarbonate
$P = 0$	0	0	T
$P < {}^{1}/_{2}\ T$	0	$2P$	$T - 2P$
$P = {}^{1}/_{2}\ T$	0	$2P$	0
$P > {}^{1}/_{2}\ T$	$2P - T$	$2(t - p)$	0
$P = T$	T	0	0

P = Phenolphthalein alkalinity
T = Total alkalinity

EXAMPLE 7

- A water sample is tested for phenolphthalein and total alkalinity. If the phenolphthalein alkalinity is 10 mg/L as $CaCO_3$, and the total alkalinity is 52 mg/L as $CaCO_3$, what are the bicarbonate, carbonate, and hydroxide alkalinities of the water?

P = 10 mg/L
T = 52 mg/L
$P < {}^1/_2 T$

EXAMPLE 7 CONT'D

$Hydroxide =$

$Carbonate =$

$Carbonate =$

$Carbonate =$

$Bicarbonate =$

$Bicarbonate =$

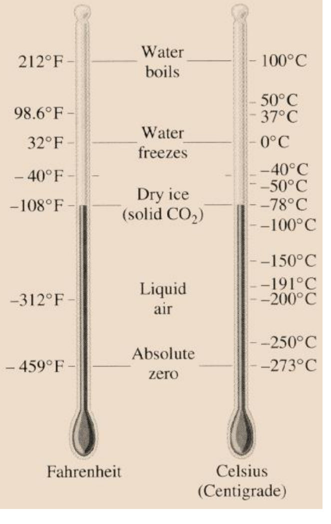
$Bicarbonate =$

$Bicarbonate =$

TEMPERATURE CONVERSIONS

TEMPERATURE SCALES

The **Fahrenheit** scale is named for the 18th-century German physicist Daniel Fahrenheit.
His scale is based on 32 for the freezing point of water and 212 for the boiling point of water, the interval between the two being divided into 180 parts.
The scale was in common use in English speaking countries until the 1970's when Europe and Canada adopted the centigrade (Celsius) scale.
The U.S is the only country that still uses the Fahrenheit scale.



The **Celsius** temperature scale is named for the in the Swedish astronomer Anders Celsius who invented the scale in 1742.

The scale is based on 0 for the freezing point of water and 100 for the boiling point of water.

It is sometimes called the centigrade scale because of the 100-degree interval between the defined points.

24

TEMPERATURE FORMULAS

- Degrees Fahrenheit

$$°F = (°C)(1.8) + 32$$

Remember your
Order of Operations!!

- Degrees Celsius

$$°C = \frac{(°F - 32)}{1.8}$$

EXAMPLE 8

- Determine the temperature in °F if the temperature is measured as 43°C.

$$°F = (°C)(1.8) + 32$$

EXAMPLE 9

- Water temperature is measured with a pH probe to be $87\ °F$. What is this in Celsius?

$$°C = \frac{(°F - 32)}{1.8}$$

LANGELIER SATURATION INDEX (LSI)

LANGELIER SATURATION INDEX

- Used to determine the stability of the water
  - Aggressive vs scale forming
  - More negative the number = more aggressive water
  - More positive the number = more scale forming water

$$LSI\ -pH\ -\ pH_S$$

- pH_S = pH of Saturation
  - Temperature (°C)
  - Total Dissolved Solids (TDS in mg/L)
  - Alkalinity (mg/L as $CaCO_3$)
  - Calcium Hardness (mg/L as $CaCO_3$)

LANGELIER SATURATION INDEX

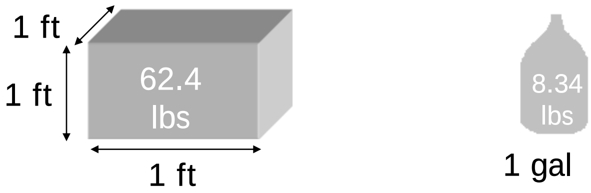
Corrosivity Characteristics as Addressed by Indices		
Corrosive Characteristics	Langelier Index (LSI)	Aggressive Index (AI)
Highly Aggressive	< - 2.0	< 10.0
Moderately Aggressive	- 2.0 to < 0.0	10.0 to < 12.0
Non-aggressive	> 0.0	> 12.0

SPECIFIC GRAVITY AND DENSITY

DENSITY

- weight per unit volume
  - solids and gases expressed in lb/ft^3
  - liquids measured in lb/gal or lb/ft^3
- density of water varies slightly with temperature and pressure
- density of gases changes significantly with changes in temperature and pressure

DENSITY OF WATER



The density of water is

8.34 lbs/gal

or

62.4 lbs/ft^3

SPECIFIC GRAVITY

- compares density of a substance to a standard density
- does not have units
- for solids and liquids
  - compare to standard density of water
    - 62.4 lb/ft^3
    - 8.34 lb/gal

SPECIFIC GRAVITY

$$Specific\ Gravity = \frac{weight\ of\ substance}{weight\ of\ water}$$

- Weights can be measured in $^{lb}/_{gal}$ or $^{lb}/_{ft^3}$
  - Be sure the units are consistent within the equation

EXAMPLE 10

- Determine the specific gravity of a liquid chemical that has a density of 10.5 lb/gal.

$$Specific\ Gravity = \frac{weight\ of\ substance}{weight\ of\ water}$$

COMPOSITE SAMPLES

COMPOSITE SAMPLES

- Composite samples
  - Representative of average water quality of location over a period of time
  - Series of grab samples mixed together
  - Determines average concentration
  - Not suitable for all tests

$$Composite\ Sample\ Single\ Portion = \frac{(Instantaneous\ Flow)(Total\ Sample\ Volume)}{(Number\ of\ Portions)(Average\ Flow)}$$

EXAMPLE 11

- Filter effluent flows at 2.0 gpm/ft^2 on average. You want to collect 5 samples for a composite sample of 10 gallons. If the water is flowing at 2.7 gpm/ft^2 at the time of sampling, what should the volume of sample #1 be in gallons?

$$Composite\ Sample\ Single\ Portion = \frac{(Instantaneous\ Flow)(Total\ Sample\ Volume)}{(Number\ of\ Portions)(Average\ Flow)}$$

EXAMPLE 11 CONT'D

Avg flow= 2.0 gpm/ft^2
samples = 5
Total volume = 10 gal
Inst. Flow = 2.7 gpm/ft^2

$$Composite\ Sample\ Single\ Portion = \frac{(Instantaneous\ Flow)(Total\ Sample\ Volume)}{(Number\ of\ Portions)(Average\ Flow)}$$

THRESHOLD ODOR NUMBER

THRESHOLD ODOR NUMBER (TON)

- Threshold Odor Numbers are whole numbers that indicate how many dilutions it takes to produce odor-free water
- Dilute multiple volumes of the odored water to 200 mL with odor free water
  - Include 2 blanks (2 - 200 mL flasks of odor free water)
  - After heating and shaking flasks, smell each flask (starting with the pure odor free water) proceeding from the lowest to the highest concentration of sample water
  - Record the volume of sample water in the first flask an odor is detected by each tester

THRESHOLD ODOR NUMBER (TON)

$$TON = \frac{A + B}{A}$$

- Where A = volume of odor causing sample

  and B = volume of odor free water

$$A + B \text{ will always} = 200\ mL$$

EXAMPLE 12

- Find the TON when odor is first detected in a flask containing 50 mL of sample water.

$$TON = \frac{A + B}{A}$$

$$TON = \frac{50\ mL + 150\ mL}{50\ mL}$$

$A + B \text{ will always} = 200\ mL$

$$TON = \frac{200\ mL}{50\ mL}$$

$$TON = 4\ TON$$

Applied Math for Water Treatment
Laboratory Calculations

1. Mechanical seals should never exceed 160°F. What is this temperature expressed in °C?

2. A sample of water contains 25 mg/L phenolphthalein alkalinity as $CaCo_3$. If the total alkalinity of the water is 121 mg/L as $CaCo_{3,}$ what is the hydroxide, carbonate, and bicarbonate alkalinity?

3. What is the percent removal across a settling basin if the influent turbidity is 8.8 ntu and the effluent turbidity at the settling basin is 0.89 ntu?

4. The phenolphthalein alkalinity of a water sample is 12 mg/L as $CaCO_3$, and the total alkalinity is 23 mg/L as CaCO3. What are the bicarbonate, carbonate, and hydroxide alkalinities of the water?

5. The atomic weight of a certain chemical is 66. If 35 grams of the chemical are used to make up a 1 liter solution, how many moles are used?

6. To determine the average turbidity coming into a plant, an operator collects 5 samples to combine into a 250 mL composite sample. The average flow at the intake is 230,000 gpd. If the flow at the time of the sample collection is 180 gpm. How many mL should the sample portion be at the time of collection?

7. A 100-milliliter (mL) sample of water is tested for alkalinity. The normality of the sulfuric acid used for titrating is 0.02 N. If 0.5 mL titrant is used to pH 8.3 and 5.7 mL titrant to pH 4.6, what are the phenolphthalein and total alkalinity of the sample?

8. A 100 mL water sample is tested for phenolphthalein alkalinity. If 2 mL of titrant is used to reach pH of 8.3 and the sulfuric acid solution has a normality of 0.02 N, what is the phenolphthalein alkalinity of the water (in mg/L as $CaCo_3$)?

9. Determine the specific gravity of a gold bar that weighs 521.47 lb and occupies a space of 0.433 ft^3.

10. What is the molarity of 2 moles of solute dissolved in 1 liter of solvent?

11. How many pounds of liquid can be pumped per day?
    Pump rate desired: 25 gpm
    Liquid weight: 74.9 lbs/ft^3

12. Find the density (lbs/ft^3) of a certain oil that has a S.G. of 0.92.

13. If 2 equivalents of a chemical are dissolved in 1.5 liters of solution, what is the normality of the solution?

14. Convert 170°F to °C.

15. Three hundred grams of calcium is how many equivalents of calcium? (The equivalent weight of calcium is 20.04.)

16. Find the density (lbs/gal) of caustic soda that has a S.G. of 1.530.

17. A gallon of solution is weighed. After the weight of the container is subtracted, it is determined that the weight of the solution is 9.1 lb. What is the density of the solution in lb/ft^3?

18. An 800 mL solution contains 1.6 equivalents of a chemical. What is the normality of the solution?

19. What is the turbidity removal efficiency through a water plant if the source water turbidity is 18.8 ntu and the treated water entering the distribution system is 0.035 ntu?

20. The magnesium content of water is 25 mg/L. How many milliequivalents/liter is this? The equivalent weight of magnesium is 12.15.)

21. The density of an unknown liquid is 74.1 lb/ft^3. What is the specific gravity of the liquid?

22. What is the iron removal efficiency through a water plant if the source water iron content is 4.25 mg/L and the treated water entering the distribution system is 0.030 mg/L?

23. A 100-milliliter (mL) water sample is tested for phenolphthalein alkalinity. If 1.40 mL titrant is used to pH 8.3 and the normality of the sulfuric acid solution is 0.02 N, what is the phenolphthalein alkalinity of the water (in mg/L as CaCO3)?

24. The effluent of a treatment plant is 23°C. What is this expressed in degrees Fahrenheit?

25. What is the specific gravity of a polymer solution that weighs 11.1 lb/gal?

26. If 2.9 moles of solute are dissolved in 0.8 liter of solution, what is the molarity of the solution?

27. Convert 17°C to degrees Fahrenheit.

28. A water sample is found to have a phenolphthalein alkalinity of 0 mg/L and a total alkalinity of 67 mg/L. What are the bicarbonate, carbonate, and hydroxide alkalinities of the water?

29. What is the density of a substance in pounds per cubic foot if it weighs 29.27 kg and occupies a space of 0.985 ft^3?

30. Alkalinity titrations on a 100-mL water sample gave the following results: 1.5 mL titrant used to pH 8.3, and 2.9 mL total titrant used to pH 4.5. The normality of the sulfuric acid was 0.02 N. What are the phenolphthalein, total, bicarbonate, carbonate, and hydroxide alkalinities of the water?

31. The magnesium content of a water source averages 0.24 mg/L. What is the percent removal if the treated water averages 0.020 mg/L Mg?

32. A 100-milliliter (mL) sample of water is tested for phenolphthalein and total alkalinity. A total of 0 mL titrant is used to pH 8.3 and 6.9 mL titrant is used to titrate to pH 4.4. The normality of the acid used for titrating is 0.02 N. What are the phenolphthalein and total alkalinity of the sample (in mg/L as CaCO3)?

33. A 1.7 molar solution is to be prepared. If a 900 mL solution is to be prepared, how many moles solute will be required?

34. A certain pump delivers 14 gallons of water per minute.
    A. How many lbs of water does the pump deliver in 24 hours?
    B. How many lbs/day will the pump deliver if the liquid weighs 8.1 lbs/gal?

35. A tank holds 1,240 gallons of a certain liquid. The specific gravity is 0.93. How many pounds of liquid are in the tank?

36. Calculate the percent removal of settleable solids if the settleable solids of the sedimentation tank influent are 16 mL and the settleable solids of the effluent are 0.8 mL/L.

37. Determine the specific gravity of a polymer solution that weighs 1067 lb/gal.

38. The molecular weight of calcium is 40. If a total of 28 grams of calcium are used in making up a 1-liter solution, how many moles are used?

39. Convert 43°C to degrees Fahrenheit.

40. If 2.3 equivalents of a chemical are dissolved in 1.4 liters of solution, what is the normality of the solution?

41. The influent to a treatment plant has a temperature of 75°F. What is the temperature expressed in degrees Celsius?

42. If the influent turbidity for a water plant is 17.5 ntu and the effluent turbidity is 0.03, what is the percent removal?

43. What is the molarity of a solution that has 0.5 moles solute dissolved in 1800 mL of solution?

44. What is the specific gravity for a solution that weighs 9.44 lb/gal?

45. To preserve a bacteriological sample, the sample must be cooled to 4°C. What is this expressed in degrees Fahrenheit?

46. What is the turbidity removal efficiency through a water plant if the source water turbidity is 22.6 ntu and the treated water entering the distribution system is 0.040 ntu?

47. A certain pump delivers 23 gallons per minute.
    A. How many lbs of water does the pump deliver in 1 minute?
    B. How many lbs/min will the pump deliver if the liquid weighs 71.9 lbs/ft^3?

48. Find the density (lbs/gal) of ferric chloride that has a S.G. of 1.140.

49. A 780 milliliter solution contains 1.3 equivalents of a chemical. What is the normality of the solution?

50. Find the density (lbs/ft^3) of potassium permanganate that has a S.G. of 1.522.

51. What is the specific gravity of an unknown liquid that has a density of 68.4 lb/ft^3?

Answers

1. 71.1°C
2. H=0; C=50; B=71
3. 89.9%
4. H=1; C=22; B=0
5. 1.88
6. 56.4 mL
7. 5 mg/L; 57 mg/L
8. 20 mg/L
9. 19.3
10. 2 M
11. 360,481.28 lb/day
12. 57.41 lb/ft^3
13. 1.33N
14. 76.67°C
15. 15
16. 12.76 lb/gal
17. 68.07 lb/ft^3
18. 2 N
19. 99.81%
20. 2.06
21. 1.19
22. 99.29%
23. 14 mg/L
24. 73.4°F
25. 1.33
26. 3.63 M
27. 62.6°F
28. H=0; C=0; B=67
29. 65.45 lb/ft3
30. H=1; C=28; B=0
31. 91.67%
32. 69%
33. 1.53 moles
34. A. 168,134.4 lb/day
    B. 163,296 lb/day
35. 9,617.69 lb
36. 95%
37. 127.94
38. 0.7
39. 109.4°F
40. 1.64 N
41. 23.89°C
42. 99.83%
43. 0.28
44. 1.13
45. 39.2°F
46. 99.82%
47. A. 191.82 lb/min
    B. 221.08 lb/min
48. 9.51 lb/gal
49. 1.67 N
50. 94.97 lb/ft^3
51. 1.10

Section 11

Miscellaneous

Overview of Water Treatment

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

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

Schematic of conventional water treatment:

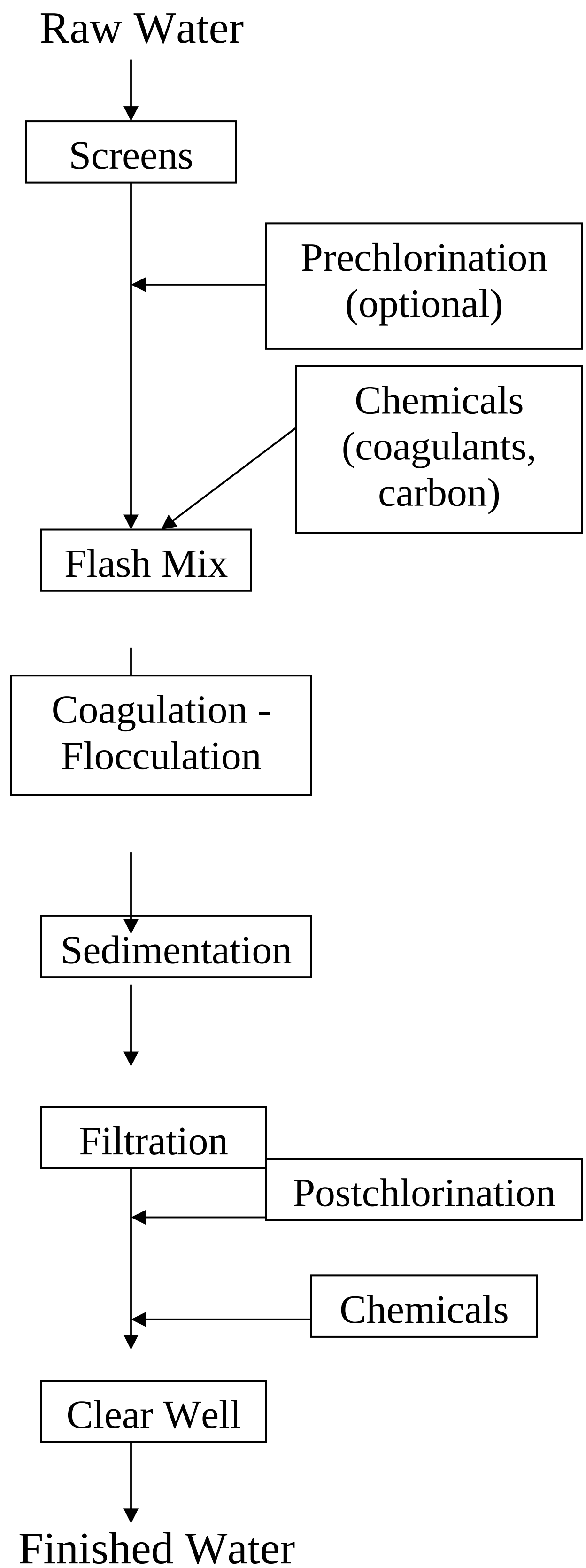
- Water is withdrawn from a lake, reservoir or river at the intake
- It is screened to remove debris
- Water then enters the flash mixing tank where coagulants and other chemicals are added
- Then it is divided into the flocculation basin
- After flocculation, the water enters the settling basins where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

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

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

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

Treatment Process



Purpose

Removes leaves, sticks, fish and other large debris.

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

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

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

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

Settles out larger suspended particles.

Filters out remaining suspended particles.

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

Phosphates control corrosion, fluoride helps prevent dental decay.

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

Common Abbreviations

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

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

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

ABC Need-to-Know Criteria for Very Small Water System Operators

ABC
Association of Boards of Certification

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- Jess Jones (Chair), Operator Training Committee of Ohio
- Richard Bond, Colorado Springs (CO) Utilities
- Don Jackson, South Carolina Environmental Certification Board
- Ken Kerri, California State University, Sacramento, Office of Water Programs
- Thomas Rothermich, City of St. Louis (MO) – Water Division
- Russ Glaser, Clark Public Utilities, Vancouver, Washington
- Martin Nutt, Arkansas Drinking Water Advisory and Operators Licensing Committee
- Wes Haskell, Old Town Water District, Old Town, Maine
- Shawn Bradford, Aquarion Water Company
- Cindy Cook, Minnesota Department of Health, Drinking Water Protection

Introduction

As part of the development of very small water system certification exams, the Association of Boards of Certification (ABC) conducted a job analysis of very small water system operators during 1998. The definition of a very small water system used during the job analysis was a system serving a maximum population of 500 with no treatment other than disinfection. The Need-to-Know Criteria was developed from the results of ABC's 1998 very small water system operator job analysis.

In 2005, ABC's Distribution Validation and Examination (V&E) Committee revised the need-to-know criteria to reflect current terminology used in the item bank. The information in this document reflects the essential job tasks performed by operators and their requisite capabilities. This document is intended to be used by certification programs and trainers to help prepare operators for entry into the profession.

How the Need-to-Know Criteria Was Developed

In 1998, a seven-member job analysis committee was formed to provide technical assistance in the development of the very small water system operator job analysis. During their meeting, this committee developed the list of the important job tasks performed by very small water system operators. The committee also verified the technical accuracy, clarity, and comprehensiveness of the job tasks. The committee then identified the capabilities (i.e., knowledge, skills, and abilities) required to perform the identified job tasks. Identification of capabilities was done on a task by task basis, so that a link was established between each task statement and requisite capability. This process resulted in a final list of 238 job tasks and 178 capabilities.

Task Inventory

A task inventory was developed from the data collected during the committee meeting. The inventory included 8-point rating scales for frequency of performance and seriousness of inadequate or incorrect performance. These two rating scales were used because they provide useful information (i.e., how critical each task is and how frequently each task is performed) pertaining to certification. The task inventory was sent to 220 certified very small water system operators throughout the United States and Canada. Ninety-three out of the 220 inventories mailed were returned for a response rate 42%.

Analysis of Ratings

The mean, standard deviation, and the percentage of respondents performing each task statement were computed. The mean was used to determine the importance of items and the standard deviation was used to identify items with a wide variation in responses. The percentage of respondents performing each task statement was used to identify tasks and capabilities commonly performed by operators throughout the United States and Canada.

A criticality value of 2(mean seriousness rating) + mean frequency rating was calculated for each item on the inventory. This formula gives extra weight to the seriousness rating in determining critical items and was appropriate because it emphasized the purpose of certification—to provide competent operators.

Core Competencies

The criticality ratings and percentage of operators reporting that they performed the tasks were used to determine what is covered on the very small water system exam. The essential tasks and capabilities that were identified through this process are called the core competencies. The following pages list the core competencies for very small water system operators. The core competencies are clustered into the following job duties:

- Operate System
- Water Quality Parameters and Sampling
- Operate Equipment
- Install, Maintain and Evaluate Equipment
- Perform Safety Duties
- Perform Administrative and Compliance Duties

Core Competencies for Very Small Water System Operators

Operate System

System Design
- Assess system demand
- Flushing program
- System layout
- System map
- Perform pressure readings
- Read blueprints, readings, and maps
- Select materials
- Select type of pipes
- Size mains

System Inspection
- Cross connection surveys/control
- Sample site plan
- Sanitary surveys
- Well inspection

Chlorine Disinfection
- Monitor disinfection process
- Evaluate disinfection process
- Adjust disinfection process

Required capabilities:
- Ability to adjust flow patterns and system units
- Ability to communicate verbally and in writing
- Ability to diagnose/troubleshoot system units
- Ability to discriminate between normal and abnormal conditions
- Ability to evaluate system units
- Ability to inspect pumps
- Ability to maintain system in normal operating condition
- Ability to monitor and adjust equipment
- Ability to perform basic math
- Knowledge of blueprint readings
- Knowledge of cathodic protection
- Knowledge of different types of joints, restraints and thrust blocks
- Knowledge of disinfection concepts and design parameters
- Knowledge of disinfection process
- Knowledge of fireflow requirements
- Knowledge of general chemistry, biology and physical science
- Knowledge of general electrical and hydraulic principles
- Knowledge of hydrology
- Knowledge of measuring instruments
- Knowledge of monitoring requirements
- Knowledge of piping material, type and size
- Knowledge of principles of measurement
- Knowledge of regulations
- Knowledge of sampling procedures and requirements
- Knowledge of sanitary survey process
- Knowledge of standards
- Knowledge of start-up and shut-down procedures
- Knowledge of testing instruments
- Knowledge of well drilling principles
- Knowledge of well-head protection

Core Competencies (continued)

Water Quality Parameters and Sampling
- Chlorine demand/residual/dosage
- Coliforms
- pH
- Temperature
- Turbidity

Required capabilities:
- Ability to calibrate instruments
- Ability to follow written procedures
- Ability to interpret Material Safety Data Sheets
- Ability to perform basic math
- Ability to recognize normal and abnormal analytical results
- Knowledge of basic laboratory equipment
- Knowledge of chemical handling and storage
- Knowledge of general biology, chemistry and physical science
- Knowledge of normal characteristics of water
- Knowledge of principles of measurement
- Knowledge of public notification requirements
- Knowledge of quality control/quality assurance practices
- Knowledge of regulations
- Knowledge of reporting requirements
- Knowledge of safety procedures
- Knowledge of sampling procedures

Operate Equipment
- Blowers and compressors
- Centrifugal pumps
- Chemical feeders
- Chlorinators
- Hydrants
- Hydraulic equipment
- Instrumentation
- Leak detectors
- Positive-displacement pumps
- Valves

Required capabilities:
- Ability to monitor, evaluate and adjust equipment
- Knowledge of drinking water concepts
- Knowledge of function of tools
- Knowledge of general electrical and mechanical principles
- Knowledge of hydraulic and pneumatic principles
- Knowledge of regulations
- Knowledge of safety procedures
- Knowledge of start-up and shut-down procedures
- Knowledge of system operation and maintenance

Core Competencies (continued)

Install, Maintain and Evaluate Equipment

Install and maintain equipment:

- Backflow prevention devices
- Chemical feeders
- Chlorinators
- Corrosion control
- Electric motors
- Hydrants
- Meters
- Pipe repair
- Pumps
- Service connection
- Storage tanks
- Taps
- Valves
- Water mains

Evaluate operation of equipment:

- Inspect equipment for abnormal conditions
- Read charts
- Read meters
- Read pressure gauges
- Troubleshoot electrical equipment

Required capabilities:

- Ability to calibrate equipment
- Ability to diagnose/troubleshoot equipment
- Ability to differentiate between preventive and corrective maintenance
- Ability to discriminate between normal and abnormal conditions
- Ability to evaluate and adjust equipment
- Ability to follow written procedures
- Ability to order necessary spare parts
- Ability to perform general maintenance
- Ability to record information
- Knowledge of corrosion control processes
- Knowledge of dechlorination and disinfection processes
- Knowledge of different types of cross-connections and approved backflow methods and devices
- Knowledge of general electrical, mechanical, hydraulic and pneumatic principles
- Knowledge of lubricant and fluid characteristics
- Knowledge of pipe fittings and joining methods
- Knowledge of piping material, type and size
- Knowledge of regulations
- Knowledge of start-up and shut-down procedures
- Knowledge of system operation and maintenance

Core Competencies (continued)

Perform Safety Procedures

- Chemical handling
- Confined space entry
- Electrical hazards
- Fire safety
- Lock-out/tag-out
- Personal protective equipment
- Traffic/work zone

Required capabilities:

- Ability to communicate verbally and in writing
- Ability to interpret Material Safety Data Sheets
- Ability to recognize unsafe work conditions/safety hazards
- Ability to select and operate safety equipment
- Knowledge of emergency plans
- Knowledge of potential causes and impact of system disasters
- Knowledge of risk management
- Knowledge of safety procedures

Perform Administrative and Compliance Duties

Administrative and Security

- Administer compliance, emergency preparedness and safety program
- Develop budget
- Develop operation and maintenance plan
- Plan and organize work activities
- Record and evaluate data
- Respond to complaints
- Write regulatory authority reports

Comply with Drinking Water Regulations

United States Exams –

- Code of Federal Regulations, Title 40, Part 141 - National Primary Drinking Water Regulations:
  - Subpart A - General definitions
  - Subpart B - Maximum contaminant levels
  - Subpart C - Monitoring and analytical requirements
  - Subpart D - Reporting and recordkeeping
  - Subpart I - Control of lead and copper
  - Subpart Q - Public notification of drinking water violations

Canadian Exams

- Provincial and territorial regulations

Required capabilities:

- Ability to assess likelihood of disaster occurring
- Ability to communicate verbally and in writing
- Ability to coordinate emergency response with other organizations
- Ability to generate written policies and procedures
- Ability to interpret and transcribe data
- Ability to organize information and review reports
- Ability to perform basic math
- Ability to perform impact assessments
- Ability to translate technical language into common terminology
- Knowledge of emergency plans
- Knowledge of local codes and ordinances
- Knowledge of monitoring and reporting requirements
- Knowledge of potential causes and impact of system disasters
- Knowledge of principles of finance
- Knowledge of principles of management
- Knowledge of principles of public relations
- Knowledge of public notification requirements
- Knowledge of public participation process
- Knowledge of recordkeeping function and policies
- Knowledge of regulations
- Knowledge of risk management
- Knowledge of system operation and maintenance

Very Small Water System Certification Exam

The very small water system certification exam evaluates an operator's knowledge of tasks related to the operation of small water systems. The content of the exam was determined from the results of the job analysis. To successfully take an ABC exam, an operator must demonstrate knowledge of the core competencies in this document.

The very small water system exam consists of 50 multiple-choice questions. The specifications for the exams are based on a weighting of the job analysis results so that they reflect the criticality of tasks performed on the job. The specifications list the percentage of questions on the exam that fall under each job duty. For a list of tasks and capabilities associated with each job duty, please refer to the list of core competencies on the previous pages.

ABC Very Small Water System Exam Specifications

Job Duty	Percent of Exam
Operate System	22%
Water Quality Parameters and Sampling	20%
Operate Equipment	10%
Install, Maintain and Evaluate Equipment	16%
Perform Safety Duties	14%
Perform Administrative and Compliance Duties	18%

Suggested References

The following are approved as reference sources for the ABC very small water system examination. Operators should use the latest edition of these reference sources to prepare for the exam.

American Water Works Association (AWWA)
- *Water Transmission and Distribution*
- *Water Quality*
- *Basic Science Concepts and Applications*
- *Water Distribution Operator Training Handbook*
- *Water System Security, A Field Guide*

To order, contact: American Water Works Association
6666 West Quincy Ave.
Denver, CO 80235

Web site: www.awwa.org
Phone: (800) 926-7337
Fax: (303) 347-0804
E-mail: custsvc@awwa.org

California State University, Sacramento (CSUS) Foundation, Office of Water Programs

- *Water Distribution System Operation and Maintenance*
- *Small Water System Operation and Maintenance*
- *Utility Management*
- *Manage for Success*

To order, contact: Office of Water Programs
California State University, Sacramento
6000 J Street
Sacramento, CA 95819-6025

Web site: www.owp.csus.edu
Phone: (916) 278-6142
Fax: (916) 278-5959
E-mail: wateroffice@owp.csus.edu

Regulations

For United States exams:

- *Code of Federal Regulations*, Title 40, Part 141 (www.gpo.gov)
- State regulations (contact information for state certification programs is available on the Certification Contacts page of ABC's web site, www.abccert.org)

For Canadian exams:

- *Guidelines for Canadian Drinking Water Quality*. Federal-Provincial-Territorial Subcommittee on Drinking Water. Ottawa, ON: Health Canada (www.hc-sc.gc.ca/waterquality)
- Provincial and territorial regulations (contact information for provincial/territorial certification programs is available on the Certification Contacts page of ABC's web site, www.abccert.org)

Very Small Water System Operators' Guidebook to Preparing for Certification

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Table of Contents

Introduction and Purpose of the Guidebook

The purpose of this guidebook is to help operators of very small water systems serving a maximum population of 100 understand the provisions and purpose of the *Final Guidelines for the Certification and Recertification of the Operators of Community and Nontransient Noncommunity Public Water Systems*. This guidebook describes the certification requirements of the EPA *Guidelines*, operator need-to-know job tasks and capabilities, exam specifications, sample test questions, and additional information relating to operator training opportunities.

Summary of the National Certification Guidelines

The *Final Guidelines for the Certification and Recertification of the Operators of Community and Nontransient Noncommunity Public Water Systems*[1] require that all community and nontransient noncommunity public water systems have a certified operator in responsible charge. A community water system is defined by the EPA as a public water system that provides water "to at least 15 service connections used by year-round residents or regularly serves at least 25 year-round residents." A nontransient noncommunity water system is defined by the EPA as a "public water system that is not a community water system and that regularly serves at least 25 of the same persons over six months per year" (p. 5921, section IV).

The objectives of the *Guidelines* are to ensure that:

- "Customers of any public water system be provided with an adequate supply of safe, potable drinking water.
- Consumers are confident that their water is safe to drink.
- Public water system operators are trained and certified and that they have knowledge and understanding of the public health reasons for drinking water standards" (p. 5919, section II.A).

To achieve these objectives the EPA developed the following operator certification guidelines. Please note that the EPA guidelines are minimum requirements. States may impose more strict requirements so it is essential for operators to contact their State Certification Program listed in the last section of this guidebook for specific state requirements.

Regulations for Certification

Each community and nontransient noncommunity water system must be under the responsible charge of an operator certified at a level equal to or greater than the system classification. This person has the authority to make decisions that affect water quality or quantity. In addition, "all operating personnel that make process control/system integrity decisions about water quality or quantity that affect public health must be certified" (p. 5919, section II.C.2). A certified operator must be available during each operating shift.

Requirements for Certification

To become certified an operator must satisfy minimum education and experience requirements and pass the appropriate certification examination. The EPA minimum requirements for certification are:

- Education - The operator must possess a high school diploma or general equivalency diploma (GED). States may allow experience and/or training to be substituted for the education requirement.
- Experience - The operator must meet the State's on-the-job experience requirement.
- Examination - The operator must pass a certification exam. The exam will cover the knowledge, skills, ability and judgment necessary to operate systems within the State.

Current operators that do not meet these newly imposed requirements may be eligible to be grandparented through the State Certification Program. If grandparenting is allowed by the State Certification Program, operators may be permitted to become certified, with the system owner's consent, without meeting all of the certification requirements. This is a restricted certificate and grandparented operators must meet all certification renewal requirements.

Among other restrictions, the *Guidelines* specify that "grandparenting is permitted only to existing operator(s) in responsible charge of existing systems which, because of State law changes to meet these guidelines, must for the first time have a certified operator." If allowed by the State, "certification for the grandparented operator must be site specific and non-transferable to other operators." "If the classification of the plant or distribution system changes to a higher level, then the grandparented certification will no longer be valid";

1. Environmental Protection Agency, 1999. Final Guidelines for the Certification and Recertification of the Operators of Community and Nontransient Noncommunity Public Water Systems. *Federal Register*, Vol. 64, No. 24–Friday, February 5, 1999.

and "if the grandparented operator chooses to work for a different water system, he or she must meet the initial certification requirements of that system" (p. 5920, section II.C.3).

Renewal

Operators that meet the certification requirements and pass the certification exam will be certified by the State Certification Program for a specific period of time. The *Guidelines* require certificates to be renewed within a period of three years. Operators must attend State approved training in order to renew their certificates.

Need-to-Know Job Tasks and Capabilities

ABC conducted a very small water system operator job analysis to identify the most critical job tasks performed by operators and the capabilities required to competently perform these job tasks. Over 450 operators were surveyed by ABC as part of this process. In the survey, operators provided data on how frequently job tasks are performed and the potential seriousness of performing these tasks incorrectly.

The results of this survey were used to develop the following Need-to-Know Criteria. The Need-to-Know Criteria is a list of the subjects that a small water system operator needs to know to properly operate a system. Tasks and their requisite capabilities performed by at least 50% of the survey respondents and with a high seriousness rating are included in this list. This list includes both community and nontransient noncommunity public water systems. Examples of nontransient noncommunity systems include schools, day-care centers, and factories.

This type of information is used as the basis for developing certification exams.

Evaluate characteristics of source water	
Job tasks	**Capabilities**
Evaluate characteristics of source water, such as:	Ability to communicate observations verbally and in writing
Bacteriological	Ability to discriminate between normal/abnormal conditions
Biological	Knowledge of normal characteristics of water
Chemical	Knowledge of wellhead protection
Physical	
Operate system	
Job tasks	**Capabilities**
Add liquid disinfectants	Ability to adjust disinfectant feed rates
Monitor, evaluate, adjust chlorine disinfection	Ability to calculate dosage rates
Inspect, maintain, repair flow measurements	Ability to confirm disinfectant strength
Inspect, maintain, repair well operation	Ability to diagnose/troubleshoot process units
Perform leak detection	Ability to interpret Material Safety Data Sheets
	Ability to maintain processes in normal operating condition
	Ability to measure disinfectant weight and volume
	Ability to perform basic math
	Ability to prepare and apply disinfectants
	Knowledge of general biology and chemistry
	Knowledge of disinfectant concepts and properties
	Knowledge of disinfectant processes and design parameters
	Knowledge of general electrical and mechanical principles
	Knowledge of normal chemical range
	Knowledge of personal protective equipment
	Knowledge of principles of measurement
	Knowledge of proper handling and storage of disinfectants
	Knowledge of proper lifting procedures
	Knowledge of regulations

Need-to-Know Criteria (Continued)

Collect, perform, and interpret laboratory analyses	
Job tasks	**Capabilities**
Collect, perform, and interpret laboratory analyses, such as:	Ability to calibrate instruments
	Ability to follow written procedures
Chlorine demand	Ability to interpret Material Safety Data Sheets
Chlorine residual	Ability to perform disinfection calculations
Microbiological	Ability to recognize abnormal analytical results
	Knowledge of general chemistry
	Knowledge of laboratory equipment
	Knowledge of principles of measurement
	Knowledge of proper disinfectant handling and storage
	Knowledge of proper safety procedures
	Knowledge of proper sampling techniques and procedures
	Knowledge of quality control and assurance practices
	Knowledge of regulations, such as the Safe Drinking Water Act
Establish safety plans and apply safety procedures	
Job tasks	**Capabilities**
Establish safety plans and apply safety procedures, in areas such as:	Ability to communicate safety hazards verbally and in writing
	Ability to demonstrate safe work habits
Chemical hazard communication	Ability to follow written procedures
Confined space entry	Ability to identify potential hazards and unsafe work conditions
Electrical grounding	Ability to operate safety equipment
General safety and health	Knowledge of potential impact of disasters on facility
Lifting	Knowledge of regulations
Lock-out/tag-out	Knowledge of risk management
Personal hygiene	
Personal protective equipment	
Slips, trips, and falls	
Operate equipment	
Job tasks	**Capabilities**
Operate equipment, such as:	Ability to evaluate and adjust operation of equipment
Chemical feeders	Ability to monitor electrical and mechanical equipment
Electronic testing equipment	Knowledge of disinfection concepts
Instrumentation	Knowledge of function of tools
Motors	Knowledge of general electrical and mechanical principles
Power tools	Knowledge of proper safety procedures
Pumps	Knowledge of regulations
	Knowledge of start-up/shut-down procedures

Need-to-Know Criteria (Continued)

Evaluate operation of equipment	
Job tasks	**Capabilities**
Check speed of equipment	Ability to adjust equipment
Inspect equipment for abnormal conditions	Ability to calibrate equipment
Perform maintenance on chemical feeders	Ability to diagnose/troubleshoot process units
Perform maintenance on pumps	Ability to discriminate between normal/abnormal conditions
Read meters	Ability to follow written procedures
Read pressure gauges	Ability to monitor electrical and mechanical equipment
	Ability to perform general maintenance and repairs
	Ability to record information
	Ability to report findings
	Ability to use hand tools
	Knowledge of facility operation and maintenance
	Knowledge of general electrical and mechanical principles
	Knowledge of proper safety procedures
	Knowledge of safety regulations
	Knowledge of start-up/shut-down procedures
Perform administrative duties	
Job tasks	**Capabilities**
Establish recordkeeping system for facility operation	Ability to communicate verbally and in writing
Organize work activities	Ability to demonstrate safe work habits
Record information relating to facility performance	Ability to determine what information needs to be recorded
Write reports	Ability to evaluate facility performance
	Ability to follow written procedures
	Ability to identify potential hazards and unsafe work conditions
	Ability to interpret and transcribe data
	Ability to operate safety equipment
	Ability to perform basic math
	Knowledge of facility operation and maintenance
	Knowledge of monitoring and reporting requirements
	Knowledge of recordkeeping function and policies
	Knowledge of regulations

Exam Specifications

The very small water system certification exam evaluates an operator's knowledge, skills, ability and judgment related to the operation of very small water systems. The Need-to-Know Criteria presented in the previous section of this guidebook results in the recommended specifications shown below for an exam. Each state determines the content of its certification exams. Please contact your State Certification Program listed in the last section of the guidebook for any information they may provide to applicants.

Recommended Very Small Water System Exam Specifications

Job Duty	Percent of Exam
Evaluate characteristics of source water	7%
Operate system	18%
Collect, perform, and interpret laboratory analyses	11%
Establish safety plans and apply safety procedures	25%
Operate equipment	10%
Evaluate operation of equipment	13%
Perform administrative duties	16%

Please refer to the Need-to-Know Criteria on the previous pages for a listing of the tasks and capabilities associated with each job duty.

Sample Test Questions

The following questions are provided as examples of the types of questions that might be covered on your certification exam. These questions may help prepare you for certification by identifying areas in which you need additional study. The correct answers and reference material for each question are found in the following section. If you cannot answer a question correctly, read the reference material listed for the question. The reference material will help you better understand the topic and may help you answer similar questions that may be on the certification exam.

It is unlikely that you will find any of these question duplicated on a certification exam, so don't try to memorize the questions and answers. Many operators find it is helpful to contact their State Certification Program listed in the last section of the guidebook to request information about the certification exam. Some, but not all, certification programs will provide a list of suggested study material, topics covered on the exam and sample exam questions.

These sample questions should <u>not</u> be used in place of other training materials and courses. The "Training Opportunities and Resources" section of this guidebook contains additional information.

1. If a customer complains about the drinking water characteristics, the operator should record the complaint and
   A. Investigate immediately
   B. Investigate only if more complaints are received
   C. Inform the customer that the water should be boiled
   D. Inform the customer that the water is safe

2. What term is used when a water utility divides its total operating expenses into the total revenue?
   A. Debt ratio
   B. Operating ratio
   C. Credit ratio
   D. Coverage ratio

3. How often should operation data, such as flow rate, amount of water treated, dosage of chemical, and reservoir levels be recorded?
   A. Twice a day
   B. Daily
   C. Weekly
   D. Monthly

4. Which of the following is the most important reason to keep daily records of operational data?
   A. Maintain records for customer billing
   B. Document the need for an increased budget
   C. Provide insurance data
   D. Document that safe drinking water has been delivered to customers

5. Under the requirements of the Safe Drinking Water Act, it is the duty of the water purveyor to deliver potable water of proper quantity only as far as the
   A. Entry point of the distribution system
   B. Customer's curb box and service connection
   C. Consumer's tap inside the home
   D. Furthest water main blow-off or sampling point

6. According to the Safe Drinking Water Act, the basic definition of a public water supply system is any water system that supplies water for human consumption that serves
   A. 25 homes or more for over 120 days a year
   B. The public in any capacity, no matter how small
   C. 25 or more persons for at least 30 days a year
   D. 15 service connections or over 25 persons for over 60 days a year

7. What agent is responsible for reporting lab results to the regulatory agency?
   A. Water system owner
   B. Board of Health chairperson
   C. Lab technician
   D. Sample collector

8. According to the USEPA drinking water regulations, the owner or operator of a public water system which fails to comply with applicable monitoring requirements must give notice to the public within
   A. 45 days of the violation by posting a notice at the town hall
   B. 1 year of the violation by including a letter with the water bill
   C. 3 months of the violation in a daily newspaper in the area served by the system
   D. 1 week of the violation in a letter hand delivered to customers

9. What federal law is designed to protect the safety and health of operators?
   A. OSHA
   B. FMLA
   C. FLSA
   D. ADEA

10. What federal law regulates public water supplies?
    A. Safe Drinking Water Act
    B. Clean Water Act
    C. Taft-Hartley Act
    D. Standard Methods

11. What causes water to move through pores in soil and rocks?
    A. Temperature
    B. Viscosity
    C. Barometric pressure
    D. Gravity

12. What is a commonly used indicator of possible health problems found in plants, soil, water and the intestines of humans and warm-blooded animals?
    A. Viruses
    B. Coliform bacteria
    C. Intestinal parasites
    D. Pathogenic organisms

13. What are disease producing bacteria called?
    A. Parasites
    B. New strain
    C. Sour type
    D. Pathogenic

14. What are the two main causes of hardness in water?
    A. Gold and silver
    B. Calcium and magnesium
    C. Phosphate and nitrate
    D. Oxygen and methane

15. Which source of water has the greatest natural protection from bacterial contamination?
    A. Shallow well
    B. Deep well in gravel
    C. Surface water
    D. Spring

16. What device measures the flow rate of gases?
    A. Parshall flume
    B. Rotameter
    C. Float
    D. Weir

17. How often should preventive maintenance for equipment be performed?
    A. Once every week
    B. After a breakdown
    C. According to manufacturer recommendations
    D. When time permits

18. Dynamic head is best described as the
    A. Velocity of water in a main at full pumping pressure
    B. Total energy that a pump must develop for pumping to take place
    C. Total pressure in feet of head, measured at the pump discharge during periods of rest in the system
    D. Pumping end of any device used to force water into a pressure system

19. Which of the following terms refers to excessive internal pressure, which may be several times the normal operating pressure and can seriously damage hydropneumatic tanks, valves, and the piping network?
    A. Air charge
    B. Flow rate pressure
    C. Water hammer
    D. Hydraulic charge

20. Which of the following should an operator investigate first when well pump and control problems occur?
    A. Depth of supply
    B. Piping
    C. Electricity
    D. Water leaks

21. Most pumps must be primed before startup in order to
    A. Calculate flow rate
    B. Prevent reverse flow
    C. Start the flow of water
    D. Prevent hammer

22. What is the purpose of a check valve?
    A. Regulate the rate of flow through the discharge pipe
    B. Act as automatic shutoff valve when the pump stops
    C. Permit air to escape from the pipe
    D. Prevent clogging of the suction line

23. What is the primary purpose of a preventive maintenance program?
    A. Increase the use of backup equipment
    B. Correct equipment breakdowns
    C. Eliminate inventory of spare parts
    D. Avoid future equipment problems

24. A mixture of air and gas is considered hazardous when the mixture exceeds what percentage of the lower explosive limit (LEL)?
    A. 0%
    B. 3%
    C. 7%
    D. 10%

25. Which of the following duties should not be performed by a small system operator?
    A. Disinfect water mains
    B. Observe pump motors to detect unusual noises, vibrations or excessive heat
    C. Repair and overhaul chlorinators
    D. Wire pump, compressors and electrical components of the water system

26. What are the most important methods of ensuring operator safety?
    A. Appointing a safety officer and administrator
    B. Alerting operators of unsafe acts and conducting mandatory safety training
    C. Providing handbooks and copies of regulations
    D. Working with proper light and ventilation

27. What safety procedure should an operator always follow when mixing a solution of sodium hypochlorite (liquid bleach) and fresh water?
    A. Attend a training course on liquid chlorine from an accredited school
    B. Wear gloves and a mask when opening the containers of bleach
    C. Ask a second individual to stand nearby with an emergency breathing apparatus
    D. Wear goggles and gloves when handling hypochlorite

28. Which form of hypochlorite is the most dangerous to handle?
    A. Sodium
    B. Fluoride
    C. Calcium
    D. Chlorine

29. What are the two most important safety concerns when entering a confined space?
    A. Corrosive chemicals and falls
    B. Bad odors and claustrophobia
    C. Extreme air temperatures and slippery surfaces
    D. Oxygen deficiency and hazardous gases

30. What piece of safety equipment must an operator wear when entering a confined space?
    A. Boots
    B. Harness
    C. Gloves
    D. Goggles

31. What type of fire extinguisher should be used for fires with live electricity present?
    A. Class A
    B. Class B
    C. Class C
    D. Class D

32. Which document provides a profile of hazardous substances?
    A. CERCLA
    B. SARA
    C. CFR
    D. MSDS

33. What safety measure must an operator follow prior to working on electrical equipment?
    A. Lock out and tag out all electrical switches
    B. Put on canvas gloves
    C. Remove fuses from switch box
    D. Tell one coworker not to turn on the switch

34. What is the correct procedure for mixing acid and water?
    A. Water is added slowly to the acid
    B. Acid is added slowly to the water
    C. Water is added quickly to the acid
    D. Acid is added quickly to the water

35. What is the purpose of a pump guard?
    A. Allows operators to turn off pump in emergency situations
    B. Notifies operators of excessive temperatures
    C. Allows operators to pump against a closed discharge valve
    D. Protects operators from rotating parts

36. The most important responsibility of an operator is to provide
    A. Adequate water pressure
    B. Palatable drinking water
    C. Adequate amounts of water
    D. Safe drinking water

37. To ensure that the water supplied by a public water system meets federal and state requirements, the water system operator must regularly collect samples and
    A. Test the water at the nearest water testing laboratory
    B. Determine a sampling schedule based on the lab's recommendations
    C. Send all analysis results to the State periodically
    D. Count the number of active wells in the system

38. The major source of error when obtaining water quality information is improper
    A. Sampling
    B. Preservation
    C. Tests of samples
    D. Reporting of data

39. A composite sample should never be used when sampling for which contaminant?
    A. Benzene
    B. Nitrate
    C. Barium
    D. Bacteria

40. When should water quality samples for chlorine residual be analyzed?
    A. Immediately
    B. Within 1 hour
    C. Within 8 hours
    D. Within 24 hours

41. How many coliform samples are required per month for a water system serving a population between 25 and 100?
    A. 1
    B. 2
    C. 3
    D. 4

42. Water laboratory test calculations and results use which system?
    A. English
    B. Metric
    C. SWAG
    D. British

43. Factors of what number are used in the metric system?
    A. 5
    B. 10
    C. 12
    D. 64

44. What is the chemical formula for sulfuric acid?
    A. SA_2
    B. H_2SO_4
    C. NaOH
    D. H_2O

45. Which of the following should <u>not</u> be used to draw a sample into a pipet?
    A. Mouth
    B. Bulb
    C. Pump
    D. Straw

46. Which of the following are two types of samples?
    A. Dessicator and gooch
    B. Wet and dry
    C. Buret and flask
    D. Grab and composite

47. What two types of devices are used to collect samples?
    A. Left and right
    B. Upper and lower
    C. Automatic and manual
    D. Gas and diesel

48. How should samples that cannot be analyzed immediately be maintained until the analysis is conducted?
    A. Shaken every hour
    B. Preserved
    C. Held in an open container
    D. Stored bottom up

49. What is the most common method used in labs to test for total coliform and *E. coli*?
    A. DMA
    B. Green
    C. Colilert
    D. Lamp

50. What test method best determines chemical feed/dosage rates?
    A. Jar
    B. Turbidity
    C. Hammer
    D. Hardness

51. An empty atmospheric storage tank is 8 feet in diameter and 32 feet high. How long will it take to fill 90% of the tank volume if a pump is discharging a constant 24 gallons per minute into the tank?
    A. 7 hours 31 minutes
    B. 8 hours 21 minutes
    C. 8 hours 23 minutes
    D. 9 hours 17 minutes

52. Two columns of water are filled completely at sea level to a height of 88 feet. Column A is 0.5 inches in diameter. Column B is 5 inches in diameter. What will two pressure gauges, one attached to the bottom of each column, read?

	Column A	Column B
A.	3.8 psi	38.0 psi
B.	8.8 psi	8.0 psi
C.	20.3 psi	20.3 psi
D.	38.0 psi	38.0 psi

53. A ditch that is 4.5 feet wide, 6 feet deep, and 120 feet long has to be dug for a water line. How many cubic yards of material must be removed?
    A. 120 cubic yards
    B. 240 cubic yards
    C. 850 cubic yards
    D. 1,200 cubic yards

54. How many cubic feet of water will a rectangular tank that is 20 feet long by 15 feet wide and 10 feet high hold?
    A. 2,000 cubic feet
    B. 3,000 cubic feet
    C. 4,000 cubic feet
    D. 5,000 cubic feet

55. Calculate the chlorine demand using the following data.
    -Raw water flow is 0.75 MGD.
    -Chlorinator feed rate is 4.0 mg/L.
    -Chlorine residual is 1.8 mg/L.
    A. 0.8 mg/L
    B. 2.2 mg/L
    C. 4.0 mg/L
    D. 5.8 mg/L

56. Convert 60.5 degrees Fahrenheit to degrees Celsius.
    A. 15.8 degrees Celsius
    B. 20.6 degrees Celsius
    C. 72.0 degrees Celsius
    D. 101.2 degrees Celsius

57. Calculate drawdown, in feet, using the following data.
    -The water level in a well is 20 feet below the ground surface when the pump is not in operation.
    -The water level is 35 feet below the ground surface when the pump is in operation.
    A. 15 feet
    B. 20 feet
    C. 35 feet
    D. 55 feet

58. Calculate the volume, in gallons, of a tank that is 75 feet long, 20 feet wide, and 10 feet deep.
    A. 15,000 gallons
    B. 112,200 gallons
    C. 150,000 gallons
    D. 224,400 gallons

59. How many pounds of a chemical applied at the rate of 3 mg/L are required to dose 200,000 gallons?
    A. 3 lbs
    B. 5 lbs
    C. 16 lbs
    D. 50 lbs

60. Calculate the average weekly flow for a system with the following data.
    Sunday - 3,000 gallons Monday - 4,000 gallons Tuesday - 3,500 gallons
    Wednesday - 2,000 gallons Thursday - 3,000 gallons Friday - 3,500 gallons
    Saturday - 2,000 gallons
    A. 2,000 gpd
    B. 3,000 gpd
    C. 4,000 gpd
    D. 5,000 gpd

61. After a new water main is installed and pressure tested it should be
    A. Flushed with clean water for 24 hours and put into service
    B. Filled with a solution of 25 ppm to 50 ppm free chlorine for at least 24 hours prior to flushing
    C. Filled with clean water and allowed to sit for 5 days at full pressure before turning the water into the system
    D. Photographed so that mapping can be avoided until the system is complete

62. Chlorine demand is satisfied at the point when
    A. The reaction of chlorine with organic and inorganic materials stops
    B. Free chlorine residuals reach 2.5 mg/L
    C. An odor of chlorine is present
    D. Chlorine reaches the last tap

63. What chlorine concentration should be produced when disinfecting a well or well pump?
    A. 25 mg/L
    B. 50 mg/L
    C. 75 mg/L
    D. 100 mg/L

64. When disinfecting a new or repaired main, what is the minimum chlorine residual at the extreme end of the main after standing for 24 hours?
    A. 15 mg/L
    B. 20 mg/L
    C. 25 mg/L
    D. 30 mg/L

65. Chlorine will destroy bacteria most rapidly at what pH?
    A. 7.5
    B. 8.5
    C. 9.5
    D. 10.5

66. What is the process of adding chlorine to water until the chlorine demand has been satisfied called?
    A. Contact time
    B. Reliquefaction
    C. Hypochlorination
    D. Breakpoint chlorination

67. Which of the following pH ranges would deposit a thin film of calcium carbonate on the inside surface of a pipe?
    A. 2.0 - 3.0
    B. 4.0 - 5.0
    C. 6.0 - 7.0
    D. 8.0 - 9.0

68. Where should sodium hypochlorite (liquid bleach) be stored?
    A. Away from flammable objects, as it is a fire hazard
    B. Away from equipment that is susceptible to corrosion
    C. In closed containers at room temperature for no longer than 6 months
    D. Near the chemical feed pump day tank, to lessen operator handling risks

69. What is the most important reason for maintaining a continuous positive pressure throughout the distribution system?
    A. Prevent damage to water meters
    B. Keep pipe joints sealed
    C. Prevent contamination from backflow
    D. Maintain chlorine residual

70. A weir should be used to measure water in which of the following locations?
    A. Above ground storage tanks
    B. Household service lines
    C. Open channels
    D. Water mains

71. The pumping water level is best defined as the distance from the top of the well to the
    A. Intake screen of the pump
    B. Location where the main flow of water enters a well
    C. Water after the pump has been operating for a period of time
    D. Water level from the start of a pump test to the end of the test

72. The space between the inner or protective casing and the outer casing or drill hole should be filled with cement grout to a minimum of how many feet?
    A. 10 feet
    B. 15 feet
    C. 20 feet
    D. 35 feet

73. When bringing community water service to a home with a private well, what is the most positive method of preventing a cross connection between the two systems?
    A. Residential dual check valve
    B. Reduced pressure zone backflow preventer
    C. Complete isolation between the two systems using an air gap
    D. Pressure vacuum breaker in addition to an RPZ

74. What is the physical connection, direct or indirect, which provides the opportunity for nonpotable water to enter a conduit, pipe or receptacle containing potable water?
    A. Well testing
    B. Pump injection
    C. Bell joint clamp
    D. Cross connection

75. Which of the following causes taste problems and has a rotten egg odor?
    A. Chlorine
    B. Benzene
    C. Nitrate
    D. Hydrogen sulfide

References and Correct Answers

Information on obtaining the references listed below may be found in the "Training Opportunities and Resources" section of this guidebook.

1. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 1
   Answer: A

2. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 8.
   Answer: B

3. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 4.
   Answer: B

4. Reference: *Water Distribution System Operation and Maintenance, A Field Study Training Program*, American Water Works Association, Ch. 1.
   Answer: D

5. Reference: *Water Distribution Operator Training Handbook*, American Water Works Association, Ch. 4.
   Answer: C

6. Reference: *Water Distribution Operator Training Handbook*, American Water Works Association, Ch. 3.
   Answer: D

7. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 7.
   Answer: A

8. Reference: USEPA 40 *Code of Federal Regulations* 141.32(b)(l)
   Answer: C

9. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 6.
   Answer: A

10. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 2.
    Answer: A

11. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 3.
    Answer: D

12. Reference: *Water Distribution System Operation and Maintenance*, California State University, Ch. 6.
    Answer: B

13. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 7.
    Answer: D

14. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 7.
    Answer: B

15. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 3.
    Answer: B

16. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 5.
Answer: B

17. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 4.
Answer: C

18. Reference: *Basic Science Concepts and Applications*, American Water Works Association, Ch. 6.
Answer: B

19. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 3.
Answer: C

20. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 3.
Answer: C

21. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 3.
Answer: C

22. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 3.
Answer: B

23. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 4.
Answer: D

24. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 6.
Answer: D

25. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 1.
Answer: D

26. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 6.
Answer: B

27. Reference: *Water Distribution Operator Training Handbook*, American Water Works Association, Ch. 19.
Answer: D

28. Reference: *Introduction to Water Treatment, Principles and Practices of Water Supply Operations*, American Water Works Association, Vol. 2.
Answer: C

29. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 6.
Answer: D

30. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 6.
Answer: B

31. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 7.
Answer: C

32. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 6.
Answer: D

33. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 6.
Answer: A

34. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 6.
Answer: B

35. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 6.
Answer: D

36. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 1.
Answer: D

37. Reference: *Water Distribution Operator Training Handbook,* American Water Works Association Ch. 3.
Answer: C

38. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 7.
Answer: A

39. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 7.
Answer: D

40. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 7.
Answer: A

41. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 5.
Answer: A

42. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 7.
Answer: B

43. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 7.
Answer: B

44. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 7.
Answer: B

45. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 7.
Answer: A

46. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 7.
Answer: D

47. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 7.
Answer: C

48. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 7.
Answer: B

49. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 7.
Answer: C

50. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 7.
Answer: A

51. Reference: *Basic Science Concepts and Applications*, American Water Works Association, Ch. 10 and 11.
Answer: A
Solution: 8 feet x 8 feet x 32 feet x .785 = 1607.68 cu ft
1607.68 cu ft x 7.48 gallons per cu ft = 12,025 gallons
12,025 gallons x 0.90 = 10,823 gallons
10,823 gallons / 24 gpm = 451 minutes
451 minutes = 7 hours 31 minutes

52. Reference: *Water Distribution Operator Training Handbook*, American Water Works Association, Ch. 2.
Answer: D
Solution: 88 feet x 0.433 = approximately 38 psi.

53. Reference: *Small Water System Operation and Maintenance*, California State University, Appendix.
Answer: A
Solution: 3 ft x 3 ft x 3 ft = 27 cubic yards
4.5 ft x 6 ft x 120 ft / 27 cubic yards = 120 cubic yards

54. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 5.
Answer: B
Solution: 20 ft x 15 ft x 10 ft = 3,000 cubic feet

55. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 7.
Answer: B
Solution: 4.0 mg/L - 1.8 mg/L = 2.2 mg/L

56. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 7.
Answer: A
Solution: 60.5 ^{o} F- 32 / 1.8 = 15.8 ^{o} C

57. Reference: *Small Water System Operation and Maintenance*, California State University, Appendix.
Answer: A
Solution: 35 feet - 20 feet = 15 feet

58. Reference: *Small Water System Operation and Maintenance*, California State University, Appendix.
Answer: B
Solution: 75 ft x 20 ft x 10 ft = 15,000 cu ft
15,000 cu ft x 7.48 gal/cu ft = 112,200 gal

59. Reference: *Small Water System Operation and Maintenance*, California State University, Appendix.
Answer: B
Solution: 3 mg/L x 0.2 MGD x 8.34 lbs/gal = 5 lbs

60. Reference: *Small Water System Operation and Maintenance*, California State University, Appendix.
Answer: B
Solution: 3,000 + 4,000 + 3,500 + 2,000 + 3,000 + 3,500 + 2,000 = 21,000 gal
21,000 gallons per week / 7 days per week = 3,000 gallons per day

61. Reference: *Water Transmission and Distribution*, American Water Works Association, Ch. 5.
Answer: B

62. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 5.
Answer: A

63. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 7.
Answer: B

64. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 5.
Answer: C

65. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 5.
Answer: A

66. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 5.
Answer: D

67. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 4.
Answer: D

68. Reference: *Water Treatment*, American Water Works Association, Ch. 7.
Answer: B

69. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 5.
Answer: C

70. Reference: *Small Water System Operation and Maintenance*, California State University, Appendix - Water Words.
Answer: C

71. Reference: *Water Distribution Operator Training Handbook*, American Water Works Association, Ch. 16.
Answer: C

72. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 3.
Answer: A

73. Reference: *Water Distribution Operator Training Handbook*, American Water Works Association, Ch. 14.
Answer: C

74. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 3.
Answer: D

75. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 5.
Answer: D

Training Opportunities and Resources

There are many sources of training for very small water system operators. Operator training classes may be offered by the American Water Works Association (AWWA), local water utilities, community colleges, vocational-technical schools, and so on. Training must be approved by the State to satisfy the certification and training requirements. Therefore, it is important to contact your State Certification Program listed in the next section of the guidebook for a list of State-approved training.

In addition to training opportunities available in your state, there are general reference materials that may help prepare you for certification. The following is a partial list of reference material available in the United States.

California State University, Sacramento

- *Small Water System Operation and Maintenance*
- *Water Distribution System Operation and Maintenance*
- *Water Treatment Plant Operation,* Vol. I & II

Materials may be ordered from:
Office of Water Programs
California State University, Sacramento
6000 J Street
Sacramento, CA 95819
Phone: (916) 278-6142
E-mail: wateroffice@csus.edu
Web site: http://www.owp.csus.edu

American Water Works Association

- *Water Distribution Operator Training Handbook*
- *Water Distribution System Operation and Maintenance, A Field Study Training Program*
- *Introduction to Water Treatment, Principles and Practices of Water Supply Operations*
- *Water Transmission and Distribution*
- *Water Treatment*
- *Basic Science Concepts and Applications*
- *Design and Construction of Small Water Systems*

Materials may be ordered from:
AWWA Customer Service
6666 W. Quincy Avenue
Denver, CO 80235
Phone: (800) 926-7337
E-mail: custsvc@awwa.org
Web site: http://www.awwa.org

State Certification Programs

Alabama Water & Wastewater Operator Certification Program
Water Division
AL Dept. of Environmental Mgmt.
P.O. Box 301463
Montgomery, AL 36130-1463
Phone: (334) 274-4221
Web site: http://www.adem.state.al.us/h2owebpg.html

Alaska Department of Environmental Conservation, Facility Construction & Operation
Operations Assistance Unit
410 Willoughby Ave., Ste. 105
Juneau, AK 99801-1795
Phone: (907) 465-5140
Web site: http://www.state.ak.us/local/akpages/ENV.CONSERV/dfco/dec_dfco.htm

Arizona Operator Certification Program
Arizona DEQ
3033 N. Central Av., Rm 214, MO 248B
Phoenix, AZ 85012-2801
Phone: (602) 207-4643
Web site: http://www.adeq.state.az.us/environ/water/dw/opcert.html

Arkansas Drinking Water Advisory and Operators Licensing Committee
Dept. of Health
4815 W. Markham St. MS37
Little Rock, AR 72205-3867
Phone: (501) 661-2623
Web site: http://health.state.ar.us/eng/operfram.htm

California Water Treatment Operator Certification
DHS, Certification Unit, MS 92
601 North 7th Street
P.O. Box 942732
Sacramento, CA 94234-7320
Phone: (916) 323-1221
Web site: http://www.dhs.ca.gov/ps/ddwem/technical/dwp/dwpindex.htm

Colorado Plant Operators Certification Board
4300 Cherry Creek Drive South
Denver, CO 80246-1530
Phone: (303) 692-3558
Web site: http://www.cdphe.state.co.us

Connecticut Department of Public Health - Water Supplies Section
410 Capitol Ave., MS #51 WAT
Hartford, CT 06134-0308
Phone: (860) 509-7333
Web site: http://www.state.ct.us/dph/

Delaware Office of Drinking Water
Department of Public Health
Blue Hen Corp. Center, Suite 203
655 S. Bay Road
Dover, DE 19901-4615
Phone: (302) 739-5410

Florida DEP Water/Wastewater Operator Certification Program
Bureau of Water Facilities Funding
2600 Blair Stone Rd., MS 3506
Tallahassee, FL 32399-2400
Phone: (850) 921-4019
Web site: http://www.dep.state.fl.us/water/wff/ocp/default.htm

Georgia Board of Examiners for Certification of Water & Wastewater Treatment Plant Operators & Laboratory Analysts
State Examining Boards
237 Coliseum Drive
Macon, GA 31217-3858
Phone: (912) 207-1400
Web site: http://www.sos.state.ga.us/ebd-water/

Hawaii Board of Certification of Operating Personnel in Water Treatment Plants
Safe Drinking Water Branch
Env. Mgmt. Divn., State Dept./Health
919 Ala Moana Blvd., Room 308
Honolulu, HI 96814-4920
Phone: (808) 586-4258
Web site: http://mano.icsd.hawaii.gov/doh/rules/ei1125.html
(Regulations document)

Idaho Water & Wastewater Operators Certification Boards Inc.
IWWOCB Inc.
P.O. Box 551
Lewiston, ID 83501-0551
Phone: (208) 750-1195

Illinois Drinking Water Operator Certification Program
IL EPA, Compliance Assur. Sect. #19
1021 North Grand Ave. East
P.O. Box 19276
Springfield, IL 62794-9276
Phone: (217) 785-0561
Web site: http://www.epa.state.il.us/water/drinking-water-operator

Indiana Department of Environmental Management
100 N. Senate Avenue
P.O. Box 6015
Indianapolis, IN 46206-6015
Phone: (317) 308-3307
Web site: http://www.state.in.us/idem/owm/index.html

Iowa Operator Certification Program
Water Supply Section
IA Dept. of Natural Resources
502 East 9th St.
Des Moines, IA 50319
Phone: (515) 281-8998
Web site: http://www.state.ia.us/epd/wtrq/opercert.htm

Kansas Water and Wastewater Operator Certification
Kansas Dept. of Health & Env't.
Forbes Field, Bldg. # 283
Topeka, KS 66620-0001
Phone: (785) 296-2976
Web site: http://www.kdhe.state.ks.us/water/tech.html

Kentucky Board of Certification of Water Treatment & Distribution System Operators
KY DEP, Division of Water
14 Reilly Road
Frankfort, KY 40601-1189
Phone: (502) 564-3410
Web site: http://water.nr.state.ky.us/dow/trngcat.htm

Louisiana Committee of Certification for Water and Wastewater Operators
LA Dept. of Health
Operator Certification Program
6867 Bluebonnet Blvd., Box 6
Baton Rouge, LA 70810
Phone: (225) 765-5058

Maine Board of Licensure of Water Treatment Plant Operators
ME Drinking Water Program
157 Capitol Street
10 State House Station
Augusta, ME 04333-0010
Phone: (207) 287-5678
Web site: http://janus.state.me.us/dhs/eng/water/operator.htm

Maryland State Board of Waterworks and Waste Systems Operators
2500 Broening Highway
Baltimore, MD 21224-6617
Phone: (410) 631-3167
Web site: http://www.mde.state.md.us/permit/permit_guide98/index.html
(Permit Guide document)

Massachusetts Board of Certification of Operators of Drinking Water Supply Facilities
Massachusetts DEP
Division of Water Supply
One Winter Street, 6th Floor
Boston, MA 02108
Phone: (617) 556-1191
Web site: http://www.state.ma.us/reg/boards/dw/default.htm

Michigan Advisory Board of Examiners
Environmental Assistance Division
Town Center Building
333 S. Capitol Ave., 2nd Floor
Lansing, MI 48933-2022
Phone: (517) 373-4752
Web site: http://www.deq.state.mi.us/ead/tasect/otu/

Minnesota Advisory Council on Water Supply Systems & Wastewater Treatment Facilities
MN Dept./Health, Drinking Water Prot.
121 East 7th Place, Suite 220
P.O. Box 64975
St. Paul, MN 55164-0975
Phone: (651) 215-0751
Web site: http://www.health.state.mn.us/divs/eh/dwp/pws/dwopcert/dwopmain.html

Mississippi State Department of Health
Division of Water Supply
2423 North State Street, Ste. 241
P.O. Box 1700
Jackson, MS 39215-1700
Phone: (601) 576-7518
Web site: http://www.msdh.state.ms.us/watersupply/index.htm

Missouri Department of Natural Resources
Technical Assistance Program
P.O. Box 176
Jefferson City, MO 65102-0176
Phone: (800) 361-4827
or (573) 751-1600
Web site: http://www.dnr.state.mo.us/deq/tap/oprtrain.htm

Montana Water and Wastewater Operators' Advisory Council
Department of Envir. Quality
Community Services Bureau
P.O. Box 200901
Helena, MT 59620-0901
Phone: (406) 444-2691
Web site: http://www.deq.state.mt.us/pcd/csb/certify.htm

Nebraska Department of Health & Human Services
Dept./Reg. & Licensure
301 Centennial Mall South
P.O. Box 95007
Lincoln, NE 68509-5007
Phone: (402) 471-2541
Web site: http://www.hhs.state.ne.us

Nevada State Health Division
NV Bureau of Health Prot. Services
1179 Fairview Dr. Ste. 101
Carson City, NV 89701-5405
Phone: (775) 687-6615 ext. 235
Web site: http://www.state.nv.us/health/bhps/PHE/sdwp.htm

New Hampshire Department of Environmental Services
Engineering Bureau, Water Supply
6 Hazen Drive
P.O. Box 95
Concord, NH 03302-0095
Phone: (603) 271-2410
Web site: http://www.des.state.nh.us/wseb

New Jersey Water & Wastewater Board of Examiners
NJ DEP Administrator's Office
P.O. Box 420
Trenton, NJ 08625-0420
Phone: (609) 984-7743
Web site: http://www.state.nj.us/dep

New Mexico Utility Operators Certification Program
New Mexico Environment Dept.
Facility Oper. Section / SWQB
P.O. Box 26110
Santa Fe, NM 87502-0110
Phone: (505) 827-2799
Web site: http://www.nmenv.state.nm.us/

New York Community Water System Operator Certification Program
NY State Dept. of Health
Bureau/Public Water Supply Prot.
Flanigan Square, 547 River St.
Troy, NY 12180-2216
Phone: (518) 402-7712

North Carolina Water Treatment Facility Operators Certification Board
NC DENR, Divn. of Environ. Health
1635 Mail Service Center
Raleigh, NC 27699-1635
Phone: (919) 715-9572
Web site: http://www.deh.enr.state.nc.us/

North Dakota Department of Health
1200 Missouri Avenue
P.O. Box 5520
Bismarck, ND 58502-5520
Phone: (701) 328-6626
Web site: http://www.health.state.nd.us/ndhd/environ/mf/index.htm

Ohio EPA - Certification Unit
DDAGW
122 South Front Street
P.O. Box 1049
Columbus, OH 43216-1049
Phone: (614) 644-2888
Web site: http://www.epa.ohio.gov/ddagw/ddagwmain.html

Oklahoma Waterworks & Wastewater Works Advisory Council
Oklahoma DEQ
Certification and Compliance Section
P.O. Box 1677
Oklahoma City, OK 73101-1677
Phone: (405) 702-8100
Web site: http://www.deq.state.ok.us/Water1/operatorcertification/

Oregon Water Operator Certification Program
OR Health Division
Drinking Water Section
P.O. Box 14450
Portland, OR 97293-0450
Phone: (503) 731-4899
Web site: http://www.ohd.hr.state.or.us/dwp/certif.htm

Pennsylvania State Board for Certification of Sewage Treatment Plant and Waterworks Operators
DEP - Certif., Licensing & Bonding
400 Market Street, Room 102
P.O. Box 8454
Harrisburg, PA 17105-8454
Phone: (717) 787-5236
Web site: http://www.dep.state.pa.us/dep/deputate/waterops/

Rhode Island Drinking Water Certification Board
Department of Health
Office of Drinking Water Quality
3 Capitol Hill, Room 209
Providence, RI 02908-5097
Phone: (401) 222-6867
Web site: http://www.health.state.ri.us

South Carolina Environmental Certification Board
110 Centerview Drive
P.O. Box 11409
Columbia, SC 29211-1409
Phone: (803) 896-4430
Web site: http://www.llr.state.sc.us/ecb.htm

South Dakota Operator Certification Program
DWP/DENR
Foss Building-Lower Level
523 E. Capitol Ave.
Pierre, SD 57501-3181
Phone: (605) 773-4208
Web site: http://www.state.sd.us/opercert

Tennessee Water & Wastewater Operator Certification Board
J R Fleming Training Center
2022 Blanton Drive
Murfreesboro, TN 37129-2912
Phone: (615) 898-8090
Web site: http://www.state.tn.us/environment/dca/fleming.htm

Texas Operator Certification Program
TNRCC, MC 178
P.O. Box 13087
Austin, TX 78711-3087
Phone: (512) 239-6139
Web site: http://www.tnrcc.state.tx.us/enforcement/csd/ocs/

Utah Water Operator Certification Commission
Utah Divn. of Drinking Water
150 North 1950 West
P.O. Box 144830
Salt Lake City, UT 84114-4830
Phone: (801) 536-4200
Web site: http://www.deq.state.ut.us/eqdw/

Vermont Department of Environmental Conservation
Water Supply Division
Old Pantry Building
103 South Main Street
Waterbury, VT 05671-0403
Phone: (802) 241-3400
Web site: http://www.anr.state.vt.us/dec/watersup/wsd.htm

Virginia Board for Waterworks and Wastewater Works Operators
Dept. of Profess. and Occup. Reg.
3600 West Broad Street, 5th Floor
Richmond, VA 23230-4917
Phone: (804) 367-8595
Web site: http://www.state.va.us/dpor/indexne.html

Washington Water Works Operator Certification Program
Department of Health
Division of Drinking Water
P.O. Box 47822
Olympia, WA 98504-7822
Phone: (360) 236-3137
Web site: http://www.doh.wa.gov/ehp/dw/

West Virginia Office of Environmental Health Services
Bureau for Public Health
815 Quarrier Street, Suite 418
Charleston, WV 25301-2616
Phone: (304) 558-2981
Web site: http://www.wvdhhr.org/oehs/eed/organization.html

Wisconsin Water and Wastewater Operator Certification Program
Wisconsin DNR
101 S. Webster Street
P.O. Box 7921
Madison, WI 53707-7921
Phone: (608) 266-0498
Web site: http://www.dnr.state.wi.us/org/es/science/opcert

Wyoming Operator Certification Program
WY DEQ/Water Quality Division
4th Floor Herschler Building, 4W
122 West 25th Street
Cheyenne, WY 82002-5011
Phone: (307) 777-7781
Web site: http://deq.state.wy.us/wqd/certop.htm

Record Maintenance
Water and Distribution Systems
State of Tennessee

Record	Must be kept for	Source
Bacteriological Analysis	5 years	0400-45-1-.20(1)(a)
Chemical Analysis	10 years	0400-45-1-.20(1)(a)
Actions to correct violations	3 years after last action	0400-45-1-.20(1)(b)
Written reports, summaries, communications relating to sanitary surveys	10 years after sanitary survey	0400-45-1-.20(1)(c)
Variances/exemptions	5 years after expiration	0400-45-1-.20(1)(d)
Turbidity	Next sanitary survey	0400-45-1-.20(1)(f)
Daily worksheets and shift logs	Next sanitary survey	0400-45-1-.20(1)(g)
Cross connection plans & inspection records	5 years	0400-45-1-.20(1)(h)
Complaint logs	5 years	0400-45-1-.20(1)(h)
Facility maintenance records	5 years	0400-45-1-.20(1)(h)
Storage tank inspections	5 years (required) life of tank recommended	0400-45-1-.20(1)(h)
Lead & copper	12 years	0400-45-1-.33(12)
Bacteriological records indicating disinfection of mains, tanks, filters, wells	5 years	0400-45-1-.17(8)
Flush and free chlorine residual for new taps where main is uncovered	Next sanitary survey or 3 years	0400-45-1-.17(33)
SDS	At least 30 years	29 CFR1910.1020