Monitor, evaluate and adjust

disinfection is the term for killing pathogenic organisms on water
Free chlorine residual values are based on a contact time of at least 10 minutes
Typical strength of calcium hypochlorite (available chlorine) is 65-70%
Soda ash will will raise pH
Caustic soda (NaOH) will increase pH
Alum will lower pH
chlorine will lower pH
As water temperature increases, disinfection effectiveness increases
In order to recent freezing, the maximum chlorine usage per day from a 150-lb cylinder is 43 lbs
Calcium hydroxide is used to soften water through chemical ppt
DPD (N, N-diethyl-p-phenylenediamine is used as the indicator to test for chlorine residual
The light source is a major part of the turbidimeter
Turbidity is the measurement of the clarity of water
pH is the measure of the hydrogen ion concentration
After chlorination, free chlorine residual includes OCl- and HOCl

Chlorination

The 2 most important factors impacting the effectiveness of chlorination are concentration and contact time
The organizism that is most resistant to chlorination is cryotosporidium
Disinfection of water wells with free chlorine requires chlorine at a dose of 50 mg/L for 12-24 hours
CTs are based on concentration of Cl2, contacts time, pH and temperature
Free chlorine is more a better disinfectant over chloramines because it is a stronger oxidant
Chlorine dioxide produces chlorates as undesired by-products
Chlorine produces trihalomethanes as undesired by-products
Water that is high in organic that has been chlorinated is typically associated with THMs
Chlorine dioxide is best for controlling THMs, but has its own DBPs

Corrosion control

The treatment process that controls corrosion or scaling in known as stabilization
The index that determines the calcum carbonate deposition is the Langelier saturation index-negative is corrosive, positive is scaling

Oxidation

Permanganate reactions are highly dependent on pH
Advantage to using ozone as an oxidant is it has little effect on pH
Disadvantage to using ozone as an oxidant is it leaves no residual
Drawback for UV disinfection is the potential for the bulbs to be coated by material

KMnO4 is most effective for removing iron (it's primary use, but it's a good oxidant and also used for zebra mussel control
Ozone is the best disinfectant for cryptosporidium
Ozone generators must be supplied with extremely dry air
1-3% of the air is converted to ozone in ozone generator utilizing air

fluoride

If the natural fluoride level is varying in a source water (I.e., river) the concentration in the raw water should be measured every day
Sodium fluoride crystals should be 6" thick in a saturation tank for flows <100 gpm

Flocculation basins are usually designed to provide 15-45 mins detention
Alum works best in pH range 5.8 to 8.5, or more specifically 6.5-7.2
Each milligram per liter of alum will consume 0.5 mg/L of alkalinity
Iron salt coagulants (ferric sulfate, ferric chloride) is 3.5 to 9.0 (very broad)
When using alum as a coagulant you need to increase the dosage to compensate for cold temperature
You should never mix dry alum and quicklime because explosive hydrogen gas maybe released
Particles size affects the settling rate
It takes particles to make particles, coagulation is affected by the formation of settleable particles
Colloidal particles are so small that gravity has little effect on them
Zeta potential is the natural force that keeps colloidal particles apart in water treatment
Zeta potential measures the number of excess electrons found on the surface of all particulate matter (cationic polymers effective)
-2 zeta potential indicates excellent coagulation
Sodium silicate is an excellent coagulant aid with alum
In conventional coagulation the average time to develop heavy floc particles is 30 minutes
The magnitude of the charge determines whether particles repel, stay in suspension or stick together and settle
Van der Waals forces pull particles together once they have been destabilized in the coagulation/flocculation process
Operations commonly mistakenly add time to the flocculation process
Ferric sulfate creates denser floc over alum
Dry-basis alum will consume 0.5 mg/L of alkalinity (our issue this summer with adding extra alum)
Natural zeolites can be regenerated by immersion in strong NaCl solution
if water is highly colored due to organics, it's best to acidify the water before coagulation - more effective
If silica is not carefully controlled it could inhibit floc formation (another problem we had this summer)
Water leaves the sedimentation basin via the effluent launder
In solids contact basins, the solids should be determined at least twice per day (assuming water quality stays fairly constant)
Sedimentation basins with mechanical sludge processing equipment should be drained and inspected annually
The most important reason to reduce turbidity is to remove pathogens
The most effective way to keep protozoans, viruses and bacteria from finished water is the multi-barrier approach - coag, flocculation sedimentation and filtration
The best process for removal of turbidity is coagulation, flocculation, sedimentation and filtration
Short circuiting will occur in basins with poor inlet baffles
Conventional sedimentation provides less than 0.5-log removal for crypto

In solids contactors, the weir loading rate should not exceed 5 gpm/ft
If the sludge gets too thick, solids can become re-suspended or T&O can develop
Tube and plate settlers are only effective if the floc has good settling characteristics (stable raw water quality)
Self-cleaning tube settlers should be placed at a minimum angle of 50 degrees
Parallel inclined plates should be installed at a 45 degree angle when using the shallow-depth sedimentation method
Solids-contact basins (like aurora) have a much shorter detention time than conventional because the recycled material from the sludge blanket provide quicker and more complete chemical reactions in the mixing area
Spiral flow basins introduce the water to the basin at an angle
Dissolved air-flotation is good for removing algae
Recarbonation basins are used to stabilize water after softening
Pulsating clarifiers are used to treat water that is high in color and low in turbidity
The pulsating energy helps to maintain a uniform sludge blanket (takes sludge to make sludge)
In a precipitative softening plant, 5% solids sludge is ideal
If the sludge is allowed to accumulate and compact at the bottom of the basin, 7-12% is the range
Lagoons are the most economical disposal method for sludge in a lime-soda softening plant
Before draining an in-ground sedimentation tank you must determine the level of the water table
Current regulations require water treatment wastes to be monitored DAILY
The most troublesome operating problem for sedimentation basins is the sludge collection and removal
Thickeners are used to concentrate sludge
Sand beds are used to dewater sludge
Coagulation is a chemical and physical reaction that converts non- settleable solids into settleable solids
Filter presses are used to dewater ALUM sludge, which is difficult to dewater (sponge like)
Typical Alum sludge will have 0.1 – 2.0% solids
The precipitate formed in alum coagulation is aluminum hydroxide
Sludge produced by water with relatively low turbidity can be very gelatinous and difficult to handle
Vacuum filters used to be used for dewatering. Not so much anymore. Requires a precoat of diatomaceous earth
Underground disposal of waste in wells is governed by the SDWA (Aurora's method for sludge disposal)
Recarbonation is added CO_2 to the water
Softened water has a high pH and high concentration of $CaCO_3$. Must be stabilized to prevent from ppt on filters
Conventional treatment plant with warm summer water and cold winter water – you should maintain the same bed expansion (to prevent media loss) by increasing or reduction flow rates.
Once RO membranes become fouled, they need to be cleaned with an acid wash
RO is used to treat brackish or seawater
The amount of reject water from a RO unit is dependent on the # of stages of configuration and the feed pressure
The concentration of solids from the regeneration of an ion exchange unit is in the range of 35K-45K mg/l
Fe and Mn can foul a cation exchange resin
Polyphosphates and chlorine work best for sequestering Mn
Polyphosphates should be injected into a well RIGHT AFTER it leaves the well for sequestering Fe and Mn
One an ion-exchange resin can no longer soften the water, it must be regenerated
Ion-exchange can be used for the direct treatment of groundwater if the turbidity and iron levels are low
Rock salt or pellet-type salt is the best type to use in regenerating IE softener resin
Magnetic IE resin resin has been developed to remove TOC (thought I was going to say Fe & Mn)
IE will remove ALL HARDNESS
It is impossible to produce water of less than 25 mg/L hardness when using lime-soda ash

PAC is primarily used to control organic compounds responsible for T&O
Approx 5% of the carbon is lost during reactivation for GAC
The most advantageous application point for PAC is at the raw water intake (not competing with chemicals)
Most effective way to remove T&O is by GAC or PAC
GAC is the BAT for removal of generated DBPs
Should not lose more than 2"/year of GAC in the filters. Otherwise you should reevaluate your procedures
Most effective removal for NO_3/NO_2 is anion exchange (some well systems have issues)
Bentonite Clay is an example of a weighting agent. Also bentonite is used to seal wells
The anode is a positive pole of electrolytic cell and a cathode is -negative pole of the electrolytic cell.
Cathodic metals are the least reactive metals
Basin flow rate is commonly designed not to exceed 20,000 GPD per square foot
If poorly formed floc is leaving settling basin you should increase the coagulant
The term for corrosion when two dissimilar metals come in contact is called galvanic corrosion
While $KMnO_4$ is a great oxidant and good for iron removal, too much will turn the water pink

Filtration

Filtration flow rate through a manganese greensand filter is 2-3 gpm/sq ft
When a filter is "ripening" it is becoming more efficient in particle removal
the schmutzdecke Is the fine sand and sticky mass of suspended matter that forms on the surface of a filter
Virgin greensand can be regenerated by soaking the bed in a solution of 100mg/l chlorine
Virgin greensand requires activation with $KMnO_4$

Straining suspended particles plays a minor role during filtration
Turbidity of settled water (FI) should be kept below 1-2 NTU
If filter run times are too long because turbidity is low (good water quality) it is still possible and probable to get floc breakthrough.
Gravel displacement in a filter bed with too high velocity in the BW rate could compact the media
Sedimentation is eliminated by direct filtration (pristine water quality)
Cryptosporidium can escape coagulation and pass through a granular filter
RO membranes will compact faster with higher pH
If newly installed manganese greensand was not skimmed of the fines, you will get shorter filter runs (this is the same for all filter media types)
A filter's ability to trap particles is a function of media depth and media size
If iron bacteria is causing corrosion in a filter, superchlorinate it.
Algae can shorten a filter run by clogging the filters
The most common filtration rate for slow sand filters is 0.05 GPM per square foot
Slow sand filters are clean twice scraping about 1 inch of sand off the top
Long filter runs tend to cause slime growth
Greensand filters differ from conventional filters because they remove iron and manganese by adsorption and oxidation
In filters the letters DE mean diatomaceous earth
Head lost on a green sand filter can become excessive because the grains are smaller than silica sand

Lab Analyses

Under no circumstance should a composite sample be collected for bacteriological testing
You should collect BacT sample using a grab sample
The number of monthly distribution system samples required is based on population (as well as the total # of bacT samples)
Samples to be analyzed for coliform can be refrigerated for up to 8 hours before analysis, but should be analyzed ASAP
Coliform group bacteria are the indicator organisms for pathogens (i.e., cryptosporidium, giardia, etc.)
A solution is that where one substance is dissolve in another and will not settle out
Acids, bases, and salts lacking carbon are known as inorganic compounds
When a water sample is acidified, the pH should be <2.0
Sodium thiosulfate ($Na_2S_2O_3$) is used to dechlorinate water (flushing or sampling)
Biological activity causes water samples to change quality
Water samples to be analyzed for inorganic metals should be acidified with dilute nitric acid
A standardized solution is used to determine the concentration of another solution (standardized H_2SO_4 titrant)
Membrane filtration (vs. colilert, colisure, MPN) is used to concentrate and retrieve low # of bacteria
The presence absence method is used to determine compliance for total coliforms
A typical coliform colony in the MF technique would be pink to dark red with green metallic surface sheen
In the presumptive phase of the MPN test it takes 24-48 hours for the coliforms to produce gas
Samples collected for SOC should NOT be in polypropylene
0.5 ml should be used per 100 ml aliquot for holding time for hardness analysis
Conductivity measurement helps determine the degree of mineralization of water – dissolved ion concentration
Water that is to be analyzed for inorganic metals should be filtered for dissolved metals before preserving
If you see a dramatic decline in DO, that indicates that the water is more conducive to sulfate-reducing bacteria
Alkalinity consists of bicarbonate, carbonate and hydroxide
4.0 log removal required for inactivation for viruses 99.99%
3.0 log removal required for giardia 99.9%
The highest concentration of hypochlorous acid occurs at pH 5 (most powerful disinfectant)
A 500-ml volumetric flask will most accurately measure 500-ml (beakers, cylinders, erlenmeyer, etc)
Fluosilic acid is the fluoride compound in solution form (sodium fluoride is another common form)
There are molar solutions (1 mole per liter), Molal solutions (solute divided by mass), and normal solutions. In normal solution contains 1 g equivalent weight of a compound per liter of solution
Autoclaving sterilizes with steam at 121°C and 15 psi
It is critical to have zero headspace in the sample container (vial) when collecting a sample for organic chemical contaminants
A faucet must be unused for six hours before gathering a sample for LCR Compliance testing
The TON number that will yield complaints is 5

Water Regulations

There are 4 "tiers" to public notice. Tier 1 being the most aggressive (immediate response, media, etc.) It also requires an all clear when appropriate

If a water system collects <4 samples/month

Only 1 positive sample is allowed for a system that collects less than 40 samples/month

No more than 5% positive (95% negative) allowed for coliforms

A community water system is on that has at least 15 service connections or serves 25 or more people 60 or more days each year (15/25/60)

Required sampling for coliform is at approved representative points within the distribution system (NOT RECOMMENDED at consumer's faucets) – IEPA recommends using approved dedicated sampling taps

Minimum residual chlorine entering the distribution system cannot be below 0.2 mg/l

Continuous chlorine monitoring is required per the SWTR where population is >3300

The action level for copper is 1.3 mg/L

The action level for lead is 15 ng/L

MCLG for Pb is ZERO

Turbidity is sampled at the point(s) where it enters the distribution system and the effluent of all filters

Under the SWTR samples for chlorine residuals must be collected at the same location as coliform samples

MCL for HAA5 is 0.060 mg/L or 60 ppb

MCL for THM is 0.080 mg/L or 80 ppb

Water systems are required to achieve at least a 4 log removal and/or inactivation for viruses

Sampling points for organics is at the entry point to the distribution system

Sampling points for radionuclides is at the entry point to the system

Sampling points for DBPs is at 75% representative and 25% at the farthest points

The CCR is required to be posted on the internet if the population serves >100,000

PWS that cannot meet the required removal of TOC can comply is the source-water TOC is <2.0 mg/L calculated as a qtrly running average

SWTR requires filtration. But, to avoid filtration, if the FC conc is equal or less than 20/100ml in samples before the first disinfection point in 90% of samples collected in the previous 6 months.

You must strike a balance between TOC removal and the LCR (like the issue we had with CT and LCR/alkalinity)

The US EPA mandates the language and methods for public notification

The primary source of lead in drinking water is corrosion of plumbing systems

Interior Copper piping is usually joined by solder

Fire demand can account for 40% of the total capacity of a storage system

Plastic pipe is most resistant to corrosion (It has its own issues - Potential permeation by oils gasoline and other organic compounds)

Zinc makes the best anode

24 hours is the minimum contact time when using chlorine tablet method of disinfection

Piping containing reclaimed water should be painted purple

The difference between a weak acid and a strong acid is the amount of hydrogen ions released

Minimum pressure in a distribution system is 20 psi. If the pressure falls below that, must issue a Boil Order

MCLG for chloride is 250 mg/L

MCL for nitrate is 10 mg/L

Fluoride has a primary and secondary Standard

The MCL goal for known or suspected carcinogens is always zero

Secondary MCL for TDS is 500 mg/L

RECORDS OF CHEMICAL ANALYSIS NEED TO BE KEPT FOR A MINIMUM OF 10 YEARS

Bacteriological records need to be kept for a minimum of five years

OSHA is the acronym for occupational safety and health administration
MCL = Maximum contaminant level
MCLG = Maximum contaminant level goal
Lead contaminations will cause children to have altered mental and physical development
High sulfates create "blue baby syndrome"
The health risk associated with nitrates is called methemoglobinemia

Source water

A watercourse that flows continuously is called a perennial stream
During the night, algae causes the pH of the water to decrease
Increased nutrients (i.e., PO4 and NO3) contributes to algae blooms
Hydrogen sulfide is mainly formed in groundwater sources and creates a ppt when oxidized
The Riparian Doctrine is also called the Rule of Reasonable Sharing
If a water body has high salinity and is warm, it will generally be low in DO
Reservoir turnover is caused by denser water at the surface sinking towards the bottom
Surface runoff refers to water that flows into river after a rainfall
Hikers, bicyclists, ATVs and contribution crease the threat of erosion of watershed land adjacent to a reservoir
The water-bearing geologic zone composed of material deposited by flowing rivers is called the alluvial aquifer

Copper sulfate is used to control algae
The ratio of wine to copper sulfate for controlling algae is 1:1
The correct order from smallest to largest for microorganisms is viruses, bacteria, giardia cyst
The usual available chlorine in sodium hypochlorite is 5 to 15%
Trihalomethanes are usually associated with water high in organics
Chlorine dioxide has a long-lasting residual
Turbidity will reduce the effectiveness of chlorine disinfection
Red water may be caused by iron concentrations above 0.3 mg/L
Hard water scale is usually caused by calcium carbonate

Operate equipment

Grease lubricated bearings should be regreased every 3-6 months
Check valves are used to prevent water from flowing in two directions
If only 2 rings of packing are used in a stuffing box, the joints should be staggered
The primary function for couplings is to compensate for alignment changes
Correct formula for determining Watts is Amps x Volts
Correct formula for determining BHP is HP x efficiency
Centrifugal, positive displacement and turbine are all examples of pumps
A hyperchlorinator use to feed a liquid chlorine solution into the water supply
Water hammer is most likely to be caused by closing a valve too fast
Positive displacement pumps should be operated when the suction line valves are closed in the discharge line valves are open
A 1 ton cylinder filled with Chlorine weighs approximately 3700 pounds

The operating temperature of a mechanical seal any pump should never exceed 120° F
Suction lift is the condition that exists when the source of the water supply is below the centerline of the pump
1 hp is equal to 33,000 foot-pounds per minute
Chemical feed pumps are the most common use for positive displacement pumps
The purpose of a bypass valve on a larger size gate valve is to reduce the pressure across both sides to ease opening and closing

Evaluate and maintain equipment

Mechanical seals need replacement when leakage occurs around the shaft
In a centrifugal pump, wear rings restrict the flow between the impeller discharge and the suction area
Small gaseous chlorine leaks in and around a chlorinator can be detected by the use of commercial strength ammonia
Packing should be replaced when tightening no longer controls leakage from the packing gland
Grease lubricated bearing should be re-greased every 3 to 6 months
Check valves are used to prevent water from flowing in 2 directions
If only two rings of packing are used in the stuffing box, the joint should be staggered
Couplings compensate for alignment changes
The correct formula for Watts is, Watts equals amps times volts
Centrifugal, positive displacement and turbine are all types of pumps
Water hammer is most likely to be caused by closing a valve too fast
Positive displacement pumps should be operated when suction line valves are closed and discharge line valves are open
Pinging sound any pump usually signifies cavitation
Priming replaces the air in a pump with water
A vacuum regulator stops the flow of chlorine gas if a leak develops
Mechanical seals are more appropriate for pumps operating under high section head
A pressure reducing valve is more suitable for a throttling application
a foot valve is sometimes installed on the end of the suction pipe in order to hold the prime in a centrifugal pump
Opening the discharge valve one full turn on a chlorine cylinder will permit maximum discharge
The term "C value" is used to describe the smoothness of the interior of a pipe
Tubercles can form on ductile Iron pipe
Noise from a pump is a primary indicator of bearing failure
In a centrifugal pump, the wear rings restrict the flow between the impeller discharge and the suction
The minimum separation of a correctly installed air gap is 1 inch
Air binding is caused by the release of dissolved gases in saturated cold water when pressure decreases in a filter bed
Solids contact units are most unstable during a rapid increase in temperature
The least amount of head loss in a pipeline would be due to a fully open gate Valve
Excessively hot bearings in a centrifugal pump is usually due to over lubrication
Chlorine ton containers at room temperature will deliver maximum 400 pounds per day

DETENTION TIME

Detention time helps determine the time for chemical reactions to occur within a vessel.
Detention time is determined by dividing the volume by the flow
Detention time, day = (Volume, gal)/(Flow, gal/day)
Multiply that by 24 hrs/day to get detention time in hours
Multiply that by 60 mins/hour to get detention time in minutes

Specific gravity – pure water = 1.000 (at 4 degrees C), ratio of the density of a mass of a substance to density of other. Everything else is compared to water as SG 1.000
8.34 lbs/gallon x 7.48 gallons/cu ft. = 62.38 lbs/cu ft.
If they give you the specific gravity of a substance, you can determine how many pounds/gallon or how many lbs/ cubic feet it is

Hardness, mg/L as $CaCO_3$ to convert to grains, divide by 17.12

The safe drinking water act (SDWA) directly impacts the treatment of drinking water
Typhoid is capable of being transmitted by water, so is cholera. The causative organism for cholera is VIBRIO

Safety and Emergency Preparedness

A chlorine leak in a cylinder can be detected by ammonia vapors and it will yield a white cloud
The foul, rotten egg smell that water contains is hydrogen sulfide
When Mercury std is exceeded and coliform is exceeded it poses an immediate health threat
The off gas from ozone contactor is toxic
A category one health of effect refers to an organic chemical that is a known carcinogen
Sloping is a method of preventing trench caved in during pipe installation
Methane is a colorless and odorless, lighter than air, highly flammable gas sometimes called swamp gas
Radon is colorless, odorless, mainly found in groundwater and can cause cancer

Electrical –

- Wear protective gloves
- Avoid grounding yourself in water or on pipes
- Ground all electric tools
- Lock out/tag out - When any electrical equipment is being worked on the circuit breaker should be D energized and locked out. Lockout tag out tags should include the name of the person who locked out the equipment
- Carbon dioxide extinguishers should be used on electrical fires
- Always assume electrical wires are live
- Never use metal ladders around electrical equipment
- Work with a buddy

Chemicals –

- Safe handling of chemicals – some are inert, good practice to wear PPE Wear protective clothing when working with chemicals. Goggles and face shields to protect eyes and face. Wear rubber or neoprene gloves, aprons, etc. Chemical dust. Promptly wash down or clean up any spills.
- Caustic soda precautions – alkali, will cause burns
- Chlorine precautions – respiratory irritant, will also cause chemical burns
- Spontaneous combustion can occur when activated carbon is mixed with chlorine
- The only acceptable breathing device to wear while handling chlorine leaks is self-contained breathing apparatus And it should be the positive pressure type
- One volume of liquid chlorine gas will expand at room temperature and pressure to occupy 460 volumes of gas
- The odor detection limit of chlorine gas is 0.3 ppm
- Air scrubbers are used to neutralize chlorine leaks
- The emergency repair kit for a
    - 150-lb cylinder is called emergency kit A
    - ton cylinder is called the emergency kit B
    - rail car is called the emergency kit C
- You should wear safety goggles when handling acids
- When handling fluoride chemicals personnel should wear a respirator or mask approved by NIOSH

Mechanical –

- Do not remove protective guards
- Do not wear loose clothing around rotating equipment
- Lock out drive motors before working on equipment
- Clean up all lubricant spills

Confined space – proper technique, know air quality (gas detection), have a buddy, use the tripod/harness system, etc. Complete and store the paperwork.

The most common water complaints are objectionable taste and or odors
According to the surface water treatment rule water systems must sample filter water turbidity every four hours
Surface water systems must treat, at a minimum, for coliform bacteria and turbidity
The USEPA establishes drinking water standards
A public water system is defined as at least 15 service connections or serving at least 25 individuals at least 60 days per year
According to the intro enhanced surface water treatment rule the Public water System serving a population of 10,000 or more must maintain the combined filter effluent turbidity of less than or equal to 0.3 NTU in 95% of all measurements in a month
Because it's not possible to routinely test for the presence of some organisms that EPA requires the use of treatment techniques

FORMULAS **Illinois EPA Bureau of Water – Division of Public Water Supplies** **CONVERSIONS**

$Area\,(ft^2) = Length\ in\ feet \times Width\ in\ feet$ (Area of a square or rectangle)

$Area(ft^2) = \pi\, r^2$ (Area of a circle) note: radius must be in feet

$Area(ft^2) = \frac{\pi}{4}\, x\, D^2$ (Area of a circle) note: diameter must be in feet

$Volume\,(ft^3) = Length\ in\ feet \times Width\ in\ feet \times Height\ in\ feet$

$Volume\,(ft^3) = \pi\, r^2\, x\, Height, ft$ (Volume of a circular container)
note: radius must be in feet

$Volume(ft^3) = \frac{\pi}{4}\, x\, D^2\, x\, Height, ft$ (Volume of a circular container)
note: diameter must be in feet

Detention time in minutes $= \dfrac{volume\ in\ gallons}{flow\ in\ gpm}$

$Q = VA \quad \dfrac{ft^3}{sec} = \dfrac{ft}{sec} \times ft^2$

Suction Lift Pumping Condition: $Total\ head = discharge\ head + suction\ head$

Suction Head Pumping Condition: $Total\ head = discharge\ head - suction\ head$

Specific Capacity $= \dfrac{gpm}{ft\ of\ drawdown}$

$Q_S C_S = Q_W C_W$ (solution mixing formula)

% by weight $= \dfrac{weight\ of\ chemical\ (lbs)}{wt.\ of\ chemical\ (lbs) + wt.\ of\ water\ (lbs)}$

$\pi = 3.14 \qquad \frac{\pi}{4} = .785$

r = radius D = diameter

radius = ½ diameter

1 ft^3 of water = 7.48 gallons

1 gallon of water = 8.34 pounds

1 in. of mercury = 1.13 ft. of water

1 foot of water = 0.43 psi

1 psi = 2.31 feet of water

1 grain per gallon = 17.1 mg/L

1 kilograin = 1000 grains

1 gallon = 3785 ml

1 pound = 454 grams

1 mg/L = 1 part per million (ppm)

1 ug/L = 1 part per billion (ppb)

1% solution strength = 10,000 mg/L

if chemical purity is 100%

$$lbs = MG \times mg/L \times 8.34\, lb/gal \qquad mg/L = \frac{lbs}{MG\ \ x\, 8.34\, lb/gal}$$

if chemical purity is < 100%

$$lbs\ required = \frac{MG\ x\ mg/L\ x\ 8.34 lb/gal}{\%\ purity/100} \qquad mg/L = \frac{lbs}{MG\ \ x\, 8.34\, lb/gal}\ x\ \frac{\%\ purity}{100}$$

See reverse side for formulas used with A and B exams

November 2013

****NOTE: The formulas and conversions listed below are only applicable to the Class A and Class B exam****

Ion Exchange Softening conversions: 1 grain per gallon (gpg) = 17.1 mg/L 1 kilograin = 1000 grains

For an ion exchange softening unit:

- Softening capacity in grains = ft^3 *of resin* x *the resin removal rating in grains/*ft^3

- Softener capacity in gallons during a service cycle = $\dfrac{\text{Softening capacity in grains}}{\text{raw water hardness in grains per gallon}}$

For regeneration of an ion exchange softening unit:

- pounds of salt required for regeneration

  = *lbs of salt required/kilograin of hardness removed x kilograin removal capacity of softener*

- gallons of brine required for regeneration = $\dfrac{\text{lbs of salt required for regeneration}}{\text{brine concentration in lbs salt/gallon}}$

Ion Exchange Softener Rate = *Plant Flow – Bypass Rate*

Bypass Rate for Ion Exchange Softener = $\dfrac{\text{plant flow in gpm x desired finished water hardness}}{\text{raw water hardness}}$

Filtration Rate = $\dfrac{\text{gallons per minute}}{ft^2 \text{ of filter surface area}}$

Backwash Rate = $\dfrac{\text{gallons per minute}}{ft^2 \text{ of filter surface area}}$

Overflow Rate = $\dfrac{\text{gpm}}{ft \text{ of outlet weir length}}$

Upflow Rate = $\dfrac{\text{gallons per minute}}{ft^2 \text{ of sludge surface area}}$

Circumference of a circle = $\pi \times \textit{diameter}$

Flow through velocity (in fpm) = $\dfrac{\text{flow in } ft^3/min}{\text{basin cross section in } ft^2} = \dfrac{ft}{min}$

DETENTION TIME FORMULAS:

Rectangular basins:

all in feet

$$\text{Basin Vol, gal} = (L)(W)(D)(7.48\ \text{gal/cuft})$$

For Circular basins:

$$\text{Basin Vol, gal} = (\pi)(r^2)(\text{depth, ft})(7.48\ \text{gal/cuft})$$

$$= (0.785)(\text{diameter, ft})^2(\text{depth, ft})(7.48\ \text{gal/cuft})$$

(Some people know the volume formula as πr^2depth, some people know it as $0.785 d^2$ depth - go with what you know, but REMEMBER it!!)

$$\text{DETENTION TIME, hr} = \frac{(\text{Basin Vol, gal})(24\ \text{hr/day})}{\text{Flow, gal/day}}$$

OR

$$\underset{(\text{maximum})}{\text{FLOW, gal/day}} = \frac{(\text{Basin Vol, gal})(24\ \text{hr/day})}{\text{Detention Time, hr}}$$

CHEMICAL FEED FORMULA

You absolutely need to know this!

if pure chemicals

$$\text{Lbs chemical/day} = (\text{FLOW, MGD})(\text{Concentration, mg/L})(8.34\ \text{lbs/gal})$$

$$\text{Lbs chemical} = (\text{Volume, gal})(\text{Concentration, mg/L})(8.34\ \text{lbs/gal})$$

(to calculate disinfection of a pipe or reservoir)

$$\text{Dosage, mg/L} = \frac{\text{lbs chemical/day}}{(\text{FLOW, MGD})\ (8.34\ \text{lbs/gal})}$$

if not pure chemicals

$$\text{lbs chemical/day} = \frac{(\text{FLOW, MGD})(\text{Dosage, mg/L})(8.34\ \text{lbs/gal})}{\text{\% active ingredient}/100}$$

FILTRATION

$$\text{Flow, gpm} = \frac{(\text{Flow, MGD})(1{,}000{,}000/\text{million})}{(24\ \text{hr/day})(60\ \text{min/hr})} \quad \underline{\text{AND}} \quad = \frac{\text{Total flow, gallons}}{(\text{Filter run, hr})(60\ \text{min/hr})}$$

$$\text{Filtration rate, gpm/sqft} = \frac{\text{Flow, gpm}}{\text{Surface area, sqft}}$$

$$\text{Velocity, ft/min} = \frac{\text{Water Drop, ft}}{\text{Time, min}}$$

$$\text{UFRV, gal/sqft} = \frac{\text{Volume Filtered, gal}}{\text{Filter Surface area, sqft.}} \quad \underline{\text{AND}} \quad = (\text{Filtration Rate, gpm/sqft})(\text{Filter Run, hour})(60\ \text{min/h})$$

U Filter
Run Volume

Filter BW Math

$$\text{Backwash, in/min of rise} = \frac{(\text{Backwash rate, g/min/ft}^2)(12\text{ in/ft.})}{7.48\text{ gal/ft}^3}$$

$$\%\text{ Backwash} = \frac{\text{Backwash amount, gal}}{\text{Water filtered, gal}} \times 100\%$$

$$\text{Backwash, gal} = (\text{Backwash flow, g/min})(\text{BW time, min})$$

$$\text{Water Depth, ft} = \frac{\text{Backwash volume, ft}^3}{\text{tank area, ft}^2}$$

ION EXCHANGE FORMULAS & CONVERSIONS

1 grain per gallon = 17.1 mg/L milligrams per Liter hardness as $CaCO_3$

OR 1 gpg = 17.1 mg/L

7,000 grains = 1 pound

To convert grains/gallon to mg/L

$$\text{Hardness, mg/L} = \frac{(\text{hardness, gpg})(17.1\ \text{mg/L})}{1\ \text{gpg}}$$

$$\text{Hardness, gpg} = \frac{(\text{hardness, mg/L})(1\ \text{gpg})}{17.1\ \text{mg/L}}$$

$$\text{Exchange capacity, grains} = (\text{Resin Volume, cu ft})(\text{Removal Capacity, grains/cu ft})$$

$$\text{Water Treated, gallons} = \frac{\text{Exchange capacity, grains}}{\text{Hardness removed, grains/gal}}$$

$$\text{Operating time, hr} = \frac{(\text{Water Treated, gallons})(24\ \text{hr/day})}{\text{average flow, gallons/day}}$$

$$\text{Salt Needed, lbs} = (\text{Salt Required, lbs/1000 grains})(\text{Hardness Removed, grains})$$

$$\text{Brine, gallons} = \frac{\text{Salt Needed, lbs}}{\text{Salt Solution, lbs salt/gallon of brine}}$$

Question #1

A water treatment plant treats a flow of 1.5 MGD. An examination of treatment plant design drawings reveals that the rectangular sedimentation basin is 75 feet long, 25 feet wide and has an effective (water) depth of 12 feet. Calculate the theoretical detention time in hours for the sedimentation basin.

QUESTION #1

First - calculate the basin volume in gallons.

$$\text{Basin vol, gal} = (L, ft)(W, ft)(D, ft)(7.48\ gal/cuft)$$

$$= (75 ft)(25 ft)(12 ft)(7.48\ gal/cuft)$$

$$= 168{,}300 \text{ gallons}$$

Then determine detention time in hours

$$\text{Detention time, hr} = \frac{(\text{Basin Vol, gal})(24 hr/day)}{\text{Flow, gal/day}}$$

$$= \frac{(168{,}300\ gal)(24 hr/day)}{1{,}500{,}000\ gal/day}$$

$$= 2.7 \text{ hours}$$

Question #2

What is the maximum flow in MGD for a rectangular sedimentation basin is 100 feet long, 35 feet wide and has an effective (water) depth of 16 feet, if the theoretical detention time is 2 hours?

QUESTION #2

Calculate basin vol, gal

$$\text{Basin Vol, gal} = (100\text{ft})(35\text{ft})(16\text{ft})(7.48\text{ gal/cuft})$$
$$= 418{,}880 \text{ gallons}$$

$$\text{Max Flow, gal/day} = \frac{(\text{Basin Vol, gal})(24\text{ hr/day})}{\text{Detention time, hr}}$$

$$= \frac{(418{,}880\text{ gal})(24\text{ hr/day})}{2.0\text{ hr}}$$

$$= 5{,}026{,}560 \text{ gallons/day}$$

But question wants it in MILLION gallons/day (MGD)

$$5{,}026{,}560 \div 1{,}000{,}000 = 5.026 \text{ MGD}$$

Question #3

A water treatment plant has a circular clarifier for a sedimentation basin. The treatment plant design drawings indicate that the clarifier has a diameter of 60 feet and an average water depth of 12 feet. What is the theoretical detention time in hours for the basin when the flow is 2 MGD?

QUESTION #3

Calculate basin vol, gallons

$$\text{Basin Volume, gal} = (0.785)(\text{diameter}^2)(\text{depth})(7.48\ \text{gal/cu ft})$$

$$= (0.785)(60^2)(12)(7.48)$$

$$= 253,662\ \text{gal}$$

$$\text{Detention time, hr} = \frac{(\text{Basin Vol, gal})(24\ \text{hr/day})}{\text{Flow, gal/day}}$$

$$= \frac{(253,662\ \text{gal})(24\ \text{hr/day})}{2,000,000\ \text{gal/day}}$$

$$= 3.0\ \text{hr}$$

Question #1

How many milligrams of hardness per liter are there in a water with 16 grains of hardness per gallon of water?

Question #1

$$\text{Hardness, mg/L} = \frac{(\text{Hardness, gr/gal})(17.1\ \text{mg/L})}{1\ \text{gr/gallon}}$$

$$= \frac{(16\ \text{gr/gallon})(17.1\ \text{mg/L})}{1\ \text{gr/gallon}}$$

$$= 274\ \text{mg/L}$$

Question #2

Convert the hardness of a water at 290 mg/L to grains per gallon.

Question #2

$$\text{Hardness, gr/gal} = \frac{(\text{Hardness, mg/L})(1\ \text{gr/gal})}{17.1\ \text{mg/L}}$$

$$= \frac{(290\ \text{mg/L})(1\ \text{gr/gal})}{17.1\ \text{mg/L}}$$

$$= 17\ \text{grains/gallon}$$

Question #3

An ion exchange softener contains 50 cubic feet of resin with a hardness removal capacity of 20 kilograins per cubic foot of resin. The water being treated has a hardness of 300 mg/L as $CaCO_3$. How many gallons of water can be softened before the softener will require regeneration?

Question #3

- First convert hardness from mg/L to gr/gal

$$\text{Hardness, gr/gal} = \frac{(\text{Hardness, mg/L})(1\text{ gr/gal})}{17.1\text{ mg/L}} = \frac{(300\text{ mg/L})(1\text{ gr/gal})}{17.1\text{ mg/L}} = 17.5\text{ gr/gal}$$

- Calculate the exchange capacity of the softenter in grains

$$\text{Capacity, gr} = (\text{Resin Vol, cu ft})(\text{Removal capacity, gr/cu ft})$$

$$= (50\text{ cu ft})(20{,}000\text{ grains/cu ft})$$

$$= 1{,}000{,}000\text{ gr of hardness removal capacity}$$

- Calculate the volume of water in gallons that may be treated before generation

$$\text{Water Treated, gal} = \frac{\text{Exchange Capacity, gr}}{\text{Hardness, gr/gallon}}$$

$$= \frac{1{,}000{,}000\text{ grains}}{17.5\text{ gr/gallon}}$$

$$= 57{,}143\text{ gallons}$$

Question #4

An ion exchange softening plant has two softeners that are eight feet in diameter and the units have a resin depth of six feet. The resin has a 20 kilograin removal ability. How many gallons of water can be treated if the hardness is 14 grains per gallon? If the flow rate to the softeners is 500 gallons per minute, how long will they operate before regeneration is required?

Question #4

- Calculate the total volume of softener media:

$$\text{Resin Vol, ft}^3 = (0.785)(\text{Diameter, ft})^2(\text{Depth, ft})(\text{\# of softeners})$$
$$= (0.785)(8\text{ft})^2(6\text{ft})(2)$$
$$= 603 \text{ ft}^3$$

- Calculate the total exchange capacity of the 2 softeners in grains:

$$\text{Capacity, gr} = (\text{Resin Vol, ft}^3)(\text{Removal capacity, gr/ft}^3)$$
$$= (603 \text{ ft}^3)(20{,}000 \text{ gr/ft}^3)$$
$$= 12{,}060{,}000 \text{ grains} - \text{removal capacity}$$

- Calculate the volume of water treated before exhaustion:

$$\text{Water treated, gal} = \frac{\text{Exchange capacity, gr}}{\text{Hardness, gr/gallon}}$$
$$= \frac{12{,}060{,}000 \text{ gr}}{14 \text{ gr/gallon}}$$
$$= 861{,}429 \text{ gallons}$$

- Find the length of time:

$$\text{operating time, hr} = \frac{\text{Water treated, gal}}{(\text{Avg Daily flow, gal/min})(60 \text{ min/hr})}$$
$$= \frac{861{,}429 \text{ gal}}{(500 \text{ gal/min})(60 \text{ min/hr})}$$
$$= 28.7 \text{ hours of operation}$$

Question #5

An ion exchange softener will remove 1,000,000 grains of hardness before the resin becomes exhausted. If 0.3 pounds of salt is required per 1,000 grains of hardness, how many pounds of salt are needed? If a 15-percent salt solution is used to regenerate the unit, how many gallons of brine are required? (1.39 pounds of salt is present in each gallon of 15-percent brine solution.)

Question #5

- Determine the amount of salt needed:

$$\text{Salt, lbs} = (\text{Salt required, lbs/1000gr})(\text{Hardness removal, gr})$$
$$= \left(0.3\ \frac{\text{lbs}}{1000\text{gr}}\ \text{salt}\right)(1{,}000{,}000\ \text{gr/gal})$$
$$= 300\ \text{lbs salt}$$

- Find the gallons of brine solution required:

$$\text{Brine, gal} = \frac{\text{Salt Needed, gr}}{\text{Salt Sol'n, lbs/gal of Brine}}$$

$$= \frac{300\ \text{lbs salt}}{1.39\ \text{lbs salt/gal Brine}}$$

$$= 216\ \text{gallons}\quad (15\%\ \text{solution})$$

FILTERS

Question #1

Calculate the filtration rate in GPM/ft^2 for a filter with a surface length of 25 feet and a width of 20 feet when the applied flow is 2 MGD.

FILTERS

Question #1

First convert flow from MGD to GPM

$$\text{Flow, gpm} = \frac{(\text{Flow, MGD})(1{,}000{,}000/\text{million})}{(24\,\text{hr/day})(60\,\text{min/hr})}$$

$$= \frac{(2\ \text{Million gallons/day})(1{,}000{,}000/\text{million})}{(24\,\text{hr/day})(60\,\text{min/hr})}$$

$$= 1{,}389\ \text{gpm}$$

Calculate the filter surface area

$$\text{Area, ft}^2 = \text{Length, ft} \times \text{Width, ft}$$

$$= (25\,\text{ft})(20\,\text{ft})$$

$$= 500\,\text{ft}^2$$

Calculate filtration rate:

$$\text{filtration rate, gpm/ft}^2 = \frac{\text{Flow, gpm}}{\text{Surface Area, ft}^2}$$

$$= \frac{1{,}389\ \text{gpm}}{500\ \text{ft}^2}$$

$$= 2.8\ \text{gpm/ft}^2$$

Question #2

Determine the filtration rate in GPM/ft^2 for a filter with a surface length of 30 feet and a width of 20 feet. With the influent valve closed, the water above the filter dropped 12 inches in 5 minutes.

Question #2

Calculate surface area of filter

$$\text{Area, ft} = \text{Length, ft} \times \text{width, ft}$$
$$= (30\,ft)(20\,ft)$$
$$= 60\,ft^2$$

Calculate the velocity of dropping water

$$\text{Velocity, ft/min} = \frac{\text{Water drop, ft}}{\text{time, min}}$$
$$= \frac{1\,ft}{5\,min}$$
$$= 0.2\ ft/min$$

convert 12 inches to ft = 1 ft.

Determine flow

$$\text{Flow, gpm} = (\text{Velocity, ft/min})(\text{Area, ft}^2)(7.48\ gal/ft^3)$$
$$= (0.2\ ft/min)(600\,ft^2)(7.48\ gal/ft^3)$$
$$= 898\ GPM$$

Calculate filtration rate

$$\text{Filtration Rate, gpm/ft}^2 = \frac{\text{Flow, gpm}}{\text{Area, ft}^2}$$
$$= \frac{898\ gpm}{600\,ft^2} = 1.5\ GPM/ft^2$$

Question #3

A filter with media surface dimensions of 42 feet long by 22 feet wide produces a total flow of 18.5 MG during a 73.5 hour long filter run. What is the average filtration rate in GPM/ft^2 ?

Question #3

Find the filter area

$$\text{Area, ft}^2 = \text{Length, ft} \times \text{Width, ft}$$
$$= (42\text{ ft})(22\text{ ft})$$
$$= 924\text{ ft}^2$$

Calculate the average flow

$$\text{Flow, gpm} = \frac{\text{Total Flow, gal}}{(\text{Filter Run, hr})(60\text{ min/hr})}$$
$$= \frac{18{,}500{,}000\text{ gal}}{(73.5\text{ hrs})(60\text{ min/hr})}$$
$$= 4{,}195\text{ GPM}$$

Determine average filtration rate:

$$\text{Filtration rate, gpm/ft}^2 = \frac{\text{Flow, gpm}}{\text{Area, ft}^2}$$
$$= \frac{4{,}195\text{ gpm}}{924\text{ ft}^2}$$
$$= 4.5\text{ gpm/ft}^2$$

Question #4

Determine the Unit Filter Run Volume (UFRV) for the filter from above (filter with a surface length of 25 feet and a width of 20 feet). The volume of water filtered between backwash cycles was 2.8 GPM/ft^2 during a 46-hour filter run.

Question #4

$$UFRV_{,\,gal/ft^2} = \frac{\text{Volume filtered, gal}}{\text{Filter surface area, } ft^2} \quad \text{AND,}$$

$$= \left(\text{Filtration rate}_{,\,gpm/ft^2}\right)\left(\text{filter run time, hr.}\right)(60^{m}/$$

$$= \left(2.8\ gpm/ft^2\right)\left(46\ hr\right)\left(60\ min/hour\right)$$

$$= 7{,}728\ gal/ft^2$$

Question #5

Determine the backwash pumping rate in gallons per minute (GPM) for a filter 30 feet long and 20 feet wide if the desired backwash rate is 20 GPM/ft^2

Question #5

$$\text{Area, ft}^2 = (\text{Length, ft})(\text{Width, ft})$$
$$= (30\text{ ft})(20\text{ ft})$$
$$= 600\text{ ft}^2$$

$$\text{Backwash pumping rate, gpm} = (\text{Area, ft}^2)(\text{BW Rate, gpm/ft}^2)$$
$$= (600\text{ ft}^2)(20\text{ gpm/ft}^2)$$
$$= 12{,}000\text{ gpm}$$

Question #6

Determine the volume or amount of water required to backwash a filter if the filter is backwashed for 8 minutes and the backwash flow is 12,000 GPM.

Question #6

$$\text{Backwash Water, gal} = (\text{BW Flow, gpm})(\text{BW, min})$$

$$= (12{,}000 \text{ gpm})(8 \text{ min})$$

$$= 96{,}000 \text{ gallons}$$

Question #7

How deep must the water be in a backwash tank if the tank is 50 feet in diameter and the volume of backwash water required to backwash a filter for 8 minutes is 96,000 gallons?

Question #7

Convert volume from gallons to ft^3:

$$BW, ft^3 = \frac{BW, gal}{7.48 \ gal/ft^3}$$

$$= \frac{96{,}000 \ gal}{7.48 \ gal/ft^3}$$

$$= 12{,}834 \ ft^3$$

Calculate depth:

$$\text{Water depth, } ft = \frac{BW \ vol, ft^3}{\text{Tank area, } ft^2}$$

$$= \frac{12{,}834 \ ft^3}{(0.785)(50 \ ft)^2}$$

$$= \frac{12{,}834 \ ft^3}{1962.5 \ ft^2}$$

$$= 6.54 \ ft$$

Question #8

Convert a filter backwash rate from 25 gallons per minutes per square foot to inches per minute of rise.

Question #8

$$BW,\ in/min = \frac{(BW,\ gpm/ft^2)(12\ in/ft)}{7.48\ gal/ft^3}$$

$$= \frac{(25\ gpm/ft^2)(12\ in/ft)}{7.48\ gal/ft^3}$$

$$= 40\ in/min$$

Question #9

During a filter run, the total volume of water filtered was 18.5 MG. When the filter was backwashed, 96,000 gallons of water were used. Calculate the percent of the product water used for backwashing.

Question #9

$$BW, \% = \frac{(BW, gal)(100\%)}{\text{Filtered Water, gal}}$$

$$= \frac{(96{,}000\ gal)(100\%)}{18{,}500{,}000\ gal}$$

$$= 0.5\%$$

Question #4

How many pounds of chlorine would be required to disinfect a 175,000 gallon tank to a 50 mg/L dosage?

QUESTION #4

$$\text{lbs chemical} = (\text{Vol, MG})(\text{dose, mg/L})(8.34\ \text{lbs/gal})$$

$$= (0.175\ \text{MG})(50\ \text{mg/L})(8.34\ \text{lbs/gal})$$

hint:
(175,000 gallons = 0.175 MG)

$$= 72.97\ \text{lbs} \quad \text{or} \quad 73\ \text{lbs chlorine}$$

Question #5

How many pounds of 70% HTH would be required to disinfect a 380,000 gallon tank to a 50 mg/L dosage?

QUESTION #5

$$\text{Lbs chemical} = \frac{(\text{VOL, MG})(\text{Dose, mg/L})(8.34\ \text{lbs/gal})}{\%/100}$$

$$= \frac{(0.38\ \text{MG})(50\ \text{mg/L})(8.34\ \text{lbs/gal})}{70\%/100}$$

$$= 226.37\ \text{lbs}$$

Question #6

How many pounds of 70% HTH would be required to disinfect a 6" water main 600 feet long to a 50 mg/L dosage?

QUESTION #6

First determine volume of pipe in gallons:

diameter of 6" = 0.5 ft

so, $Vol, gal = (0.785)(0.5)(0.5)(600)(7.48)$

$= 880.77$ gallons

but, to work in formula, must be in MG so,

880.77 gallon ÷ 1,000,000 = 0.00088077 MG

$$lbs, = \frac{(0.00088077 \text{ MG})(50 \text{ mg/L})(8.34 \text{ lbs/gal})}{70\%/100}$$

$= 0.52$ lbs

Question #7

How many pounds of 70% HTH would be required to disinfect 3400 feet of 4 inch water main with a 50 mg/L chlorine dosage?

QUESTION #7

First have to determine volume of water main in gallons.

$$\text{Vol, gal} = (0.785)(\text{diameter, ft})^2(\text{length, ft})(7.48\ \text{gal/cuft.})$$

$$= (0.785)(0.33\ \text{ft})(0.33\ \text{ft})(3400\ \text{ft})(7.48\ \text{gal/cuft})$$

4" = 0.33 ft

$$= \cancel{2325}\ 2174\ \text{gallons} \quad \text{or} \quad 0.00\cancel{2325}\,2174\ \text{MG}$$

$$\text{lbs} = \frac{(.00\cancel{2325}\,2174\ \text{MG})(50\ \text{mg/L})(8.34\ \text{lbs/gal})}{70\%/100}$$

1,295 lbs

$= \cancel{1,385}$ lbs

Question #8

If 32.5 pounds of 23% HFS is used in a 1,000,000 gallon storage tank, what is the fluoride dosage in mg/L?

Question #8

$$\text{Dosage, mg/L} = \frac{(\text{Feed, lbs/day})\left(\frac{\%\text{ active ingredient}}{100}\right)}{(\text{Flow, MGD})(8.34\text{ lbs/gal})}$$

$$= \frac{(32.5\text{ lbs})(23\%/100)}{(1\text{ MG})(8.34\text{ lbs/day})}$$

$$= 0.896\text{ mg/L}$$

Question #9

A 300,000 gallon tank contains water with a background residual of 0.33 mg/L fluoride. How many pounds of 25% HFS must be added to the tank to provide a 1.0 mg/L residual?

Question #9

$$\text{Dosage} = \text{Desired residual} - \text{background}$$

$$= 1.0 \text{ mg/L} - 0.33 \text{ mg/L}$$

$$= 0.67 \text{ mg/L}$$

$$\text{lbs, HFS} = \frac{(0.3 \text{ MG})(0.67 \text{ mg/L})(8.34 \text{ lbs/gal})}{25\%/100}$$

$$= 6.7 \text{ lbs, } 25\% \text{ HFS}$$