Introduction to Surface Water Treatment SDWA Regulations & Basic Chemistry May 19, 2026

Charlie Leder, PE
Hazen and Sawyer
505-236-3889; cleder@hazenandsawyer.com
NM Water Systems License, Level 4, #12411

What we will cover in this class:

- ❑ Who is in class & types of water systems we run
- ❑ What's in the raw water that our customers don't want
- ❑ SDWA Regulations on Surface Water Treatment = Da' Rules
- ❑ Basic chemistry behind water treatment chemical reactions
  - ❑ Alkalinity & pH
  - ❑ Types of coagulants & other treatment chemicals

Stick around for Parts 2 & 3 and learn:

- ❑ Part 2 at 9:10 AM: Surface Water Unit Treatment Processes and Treatment Systems
- ❑ Part 3 at 10:35 AM: Measuring & Optimizing Treatment System Performance plus quizzes to practice what you've learned!
  - ❑ Maybe some refreshers on Parts 1 & 2

Participants in this class include:

- Charlie Leder
  - Currently Senior Associate at Hazen and Sawyer
  - Former Manager – ABCWUA Plant Operations; July 2012 to May 2023
    - Managed both groundwater & surface water systems
    - NM Water Supply Level 4 license (*just renewed it!*)
  - Former Chair for Rocky Mountain Section of AWWA

- **You, the Students!!**

What we are covering now:

- ❑Who is in class & types of water systems we run
- ❑What's in the raw water that our customers don't want
- ❑SDWA Regulations on Surface Water Treatment = Da' Rules
- ❑Basic chemistry behind water treatment chemical reactions
  - ❑Alkalinity & pH
  - ❑Types of coagulants & other treatment chemicals

POLL: What NM Water Systems License Level do you now hold?

A. Level 1

B. Level 2

C. Level 3

D. Level 4

E. I don’t; I run a wastewater system!

POLL: Describe who owns your water system

A. Municipal government (Village, Town, City)

B. MDWCA

C. Regional Multi-jurisdictional Authority (Water Authority; Camino Real)

D. Investor-owned e.g., EPCOR

E. State of NM (systems at parks)

F. Other

POLL: Describe your system's water supply

- A. Surface water
- B. Groundwater with 1-2 wells
- C. Groundwater with > 2 wells
- D. Groundwater that includes treatment besides disinfection
- E. All water is purchased from a supplier (a consecutive system)

What we are covering now:

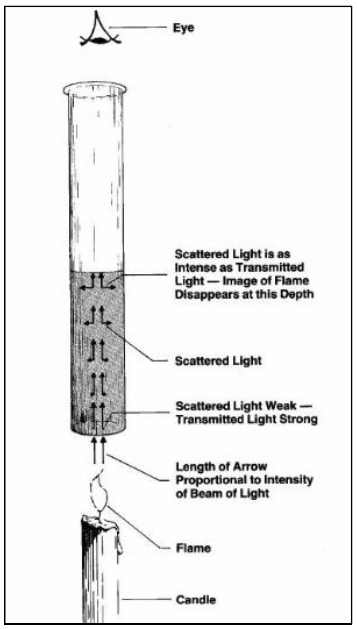
- ❑Who is in class & types of water systems we run
- ❑What's in the raw water that customers don't want
- ❑SDWA Regulations on Surface Water Treatment = Da' Rules
- ❑Basic chemistry behind water treatment chemical reactions
  - ❑Alkalinity & pH
  - ❑Types of coagulants & other treatment chemicals

What's in the water that customers don't want?

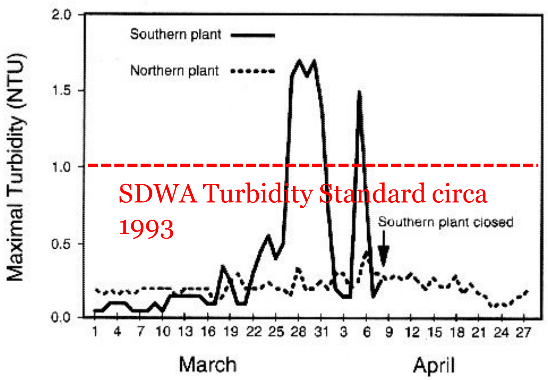
- ❑ Why do we care? "Knowing the enemy" means knowing how to attack
- ❑ Typical Surface Water Contaminants for "unpolluted sources":
  - ❑ Turbidity
  - ❑ Pathogens; Can be present even in clear cold water
  - ❑ Inorganic chemicals
    - ❑ Iron & manganese
  - ❑ Organic matter measured as Total Organic Carbon; UV254
- ❑NOT TYPICALLY FOUND: PFAS, Nitrates *(except wells too close to septic tanks)* ☹

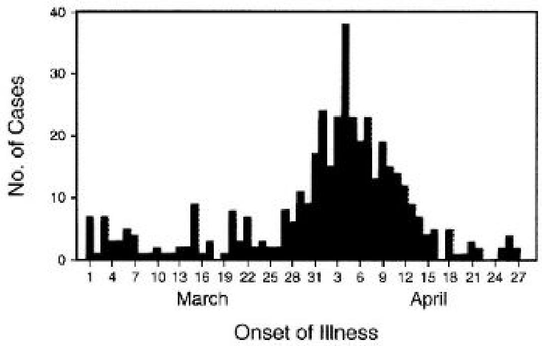
Why is removing turbidity so important?

- ❑ Customers don't like cloudy or colored water!
- ❑ Turbidity interferes with disinfection!



Why is removing turbidity so important?






Milwaukee Sentinel

Packer Plus

THURSDAY MORNING APRIL 8, 1993

**** EDITION

Boil water, mayor says

Safety of drinking supply probed in wake of mystery epidemic

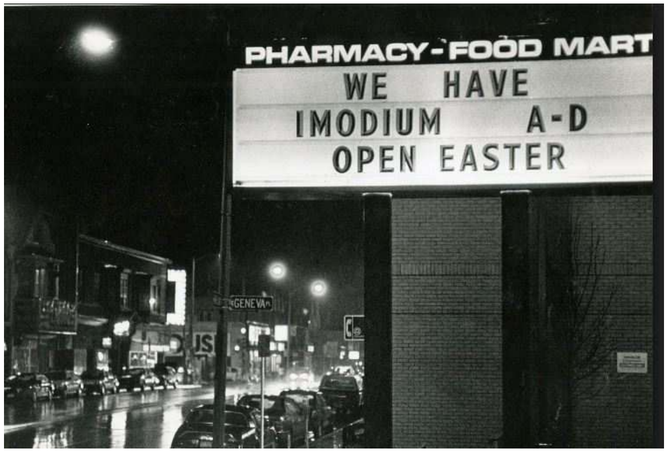


Photo images courtesy of Milwaukee Sentinel archives

QUIZ: **Of the 880,000 customers served by Milwaukee's Southern Plant, how many people are estimated to have had gastroenteritis (stomach cramps, diarrhea) during the March 1993 cryptosporidium event?**

- **A. 5,000**
- **B. 10,000**
- **C. 50,000**
- **D. 100,000**
- **E. ≈ 400,000**

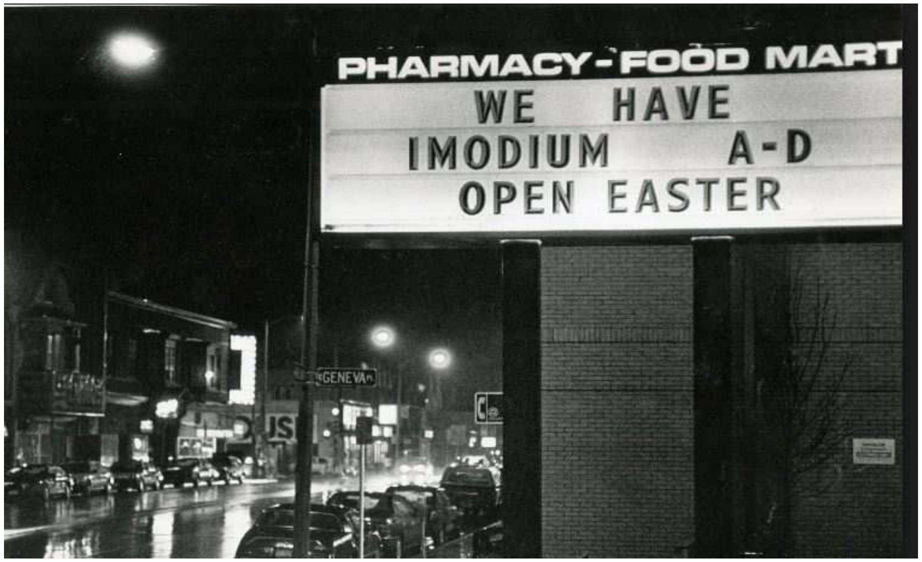


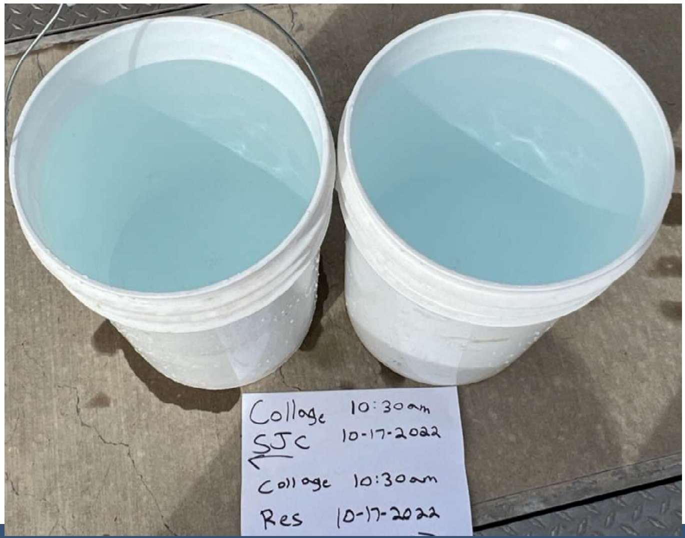
Photo image courtesy of Milwaukee Sentinel archives

What's in the water that customers also don't want (besides the SDWA primary stuff)?

- Inorganic chemicals
  - Calcium & magnesium, otherwise known as ???
    - Mostly a problem for groundwater systems
    - Can be tied up with sulfates
    - Got any alkalinity present?
  - Iron & manganese
    - Can color water & stain laundry when compounds get oxidized
  - Ca, Mg, Fe, and Mn are mostly aesthetic issues for which there are SDWA secondary standards
    - Re-focus on Manganese & its health effects now underway
  - Challenges for "deep lake" reservoirs
    - Lake stratification e.g., McLure Reservoir; Lake Maloya; Seasonal impacts on raw water quality

What's in the water that customers don't want?

- Iron and Manganese
  - Can color water & stain laundry when compounds get oxidized
  - Simple bucket tests are quite helpful & faster than waiting for lab results
  - Customers <u>WILL</u> notice!! "Will you call me when the water is safe to drink again?"



What's in the water that customers don't want?

- Organic matter measured as Total Organic Carbon (TOC)
  - UV254 absorbance: a quicker, faster, & cheaper way to measure those organics of concern besides the TOC test
- Why do we care about organic matter?
  - Increases disinfectant dose
  - Organics react w/disinfectants to form Disinfectant By-Products (DBPs)
  - To be discussed: "There's a rule for DBPs"

Other challenges for raw water quality

- Seasonal variability of reservoir quality
  - Stratification and impacts on temperature, pH, and oxygen content, particularly in deep lakes
  - Algae can be a seasonal challenge for lakes; got blue-green algae? *Currently an issue at Lake Maloya that serves the City of Raton*
- For stream or river diversions
  - Flashy turbidity conditions especially following thunderstorms
  - Burn scar runoff? Any folks here from Las Vegas or Village of Ruidoso?

What we are covering now:

- ❑Who is in class & types of water systems we run
- ❑What's in the raw water that customers don't want
- ❑SDWA Regulations on Surface Water Treatment = Da' Rules
- ❑Basic chemistry behind water treatment chemical reactions
  - ❑Alkalinity & pH
  - ❑Types of coagulants & other treatment chemicals

Da' rules for Surface Water Trt:

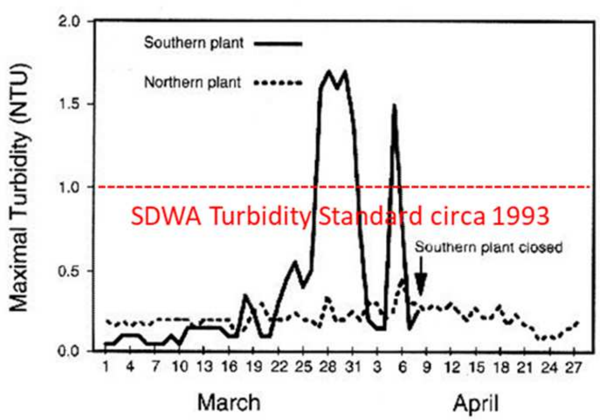
- Start w/SDWA MCLs for 125 primary contaminants
  - "Our raw water supply is pretty good" (except during disasters)
- Main Rules:
  - Surface Water Treatment Rule
  - "LT2ESWTR"
  - Revised Total Coliform Rule (RTCR); really about water quality in the distribution system & disinfection treatment; *Got any coliforms in the samples?*
- Filter Backwash Recycling Rule
- Disinfection By-Product (DBP) Rule & its impact on disinfection practices

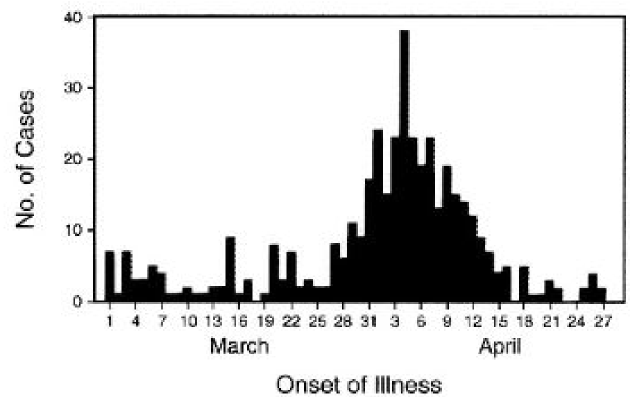
Surface Water Treatment rule(s):

- Includes enhancements by LT2ESWTR
  - LT2ESWTR = Long-term Phase 2 Enhanced Surface Water Treatment Rule
  - All about checking for cryptosporidium occurrence in your source water; "Which bin are you in?"
- Log kill goals for pathogens: 4-log for viruses, 3-log for *Giardia lamblia*, and 2-log for *cryptosporidium cysts*
- Major requirements:
  - Free Chlorine residual ≥ 0.2 mg/L at treated water's entry point & a detectable residual throughout distribution system
  - Measure & record disinfectant residual continuously and in real time if the population you serve > 3,300

Surface Water Treatment rule(s):

- Major requirements *continued*:
  - Combined filter effluent (CFE) turbidity < 0.3 NTU in 95% of your plant's turbidimeter readings
  - Old standards from the past:





  - CURRENT STANDARD: Is turbidity from an individual filter >1 NTU for 2 consecutive 15-minute readings? *Better call NMED Drinking Water Bureau and start filter diagnostics!*

QUIZ: **NM Drinking Water Bureau regulations require a utility to issue a "boil water" notice if the product water turbidity exceeds 1 NTU**

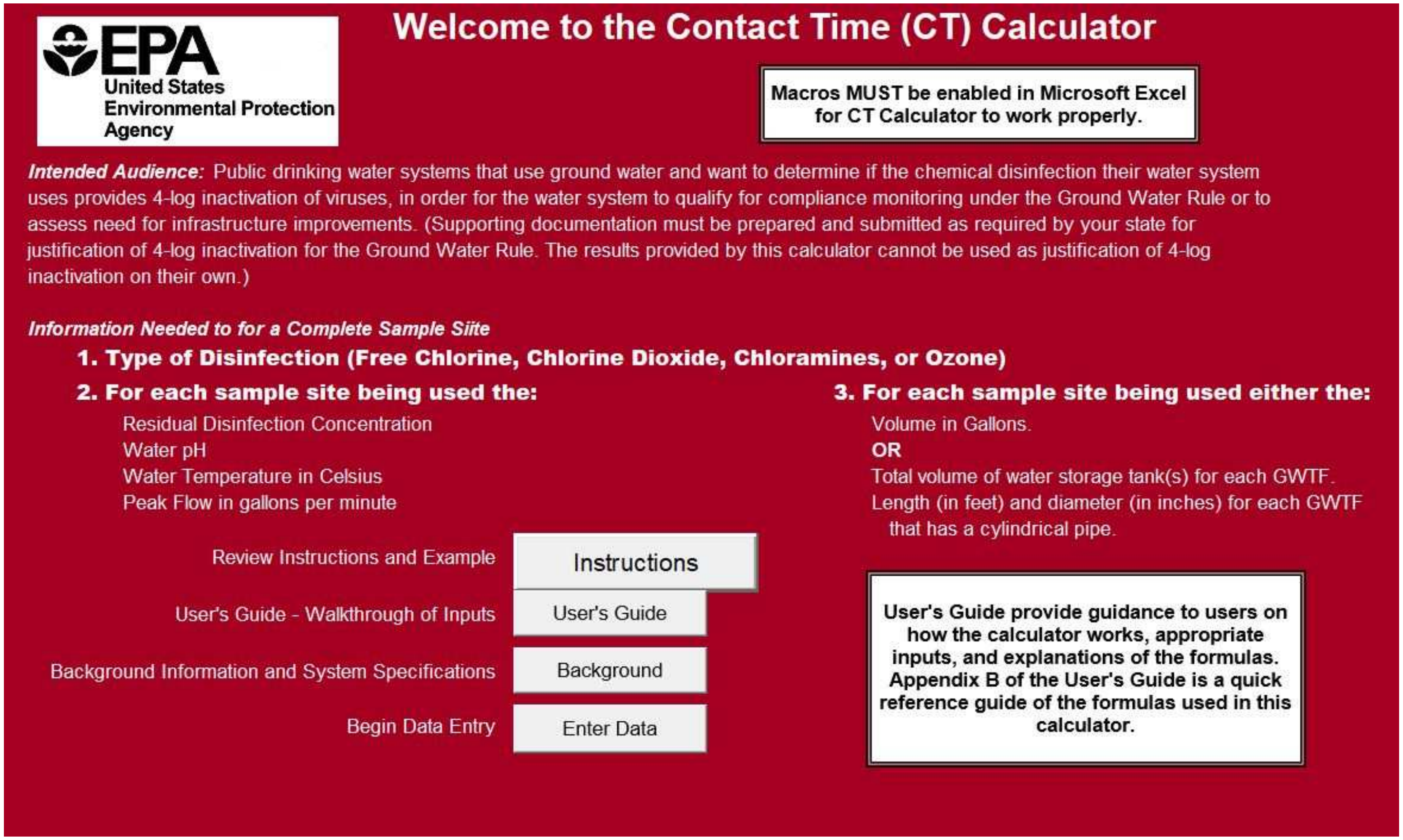
A. **TRUE**

B. **FALSE**

Surface Water Treatment rule(s):

- UNFILTERED SYSTEMS; Rules for source waters like springs or collector wells pulling from a river:
  - < 20 fecal coliforms/100 ml in 90% of all source water samples taken over 6 months
    - Between 1 and 5 samples per week need to be taken, depending on system size
    - Test for fecal coliforms in source water **DAILY** whenever its turbidity > 1 NTU)
  - < 5 NTU before applying the disinfectant based on readings taken every 4 hours (*must have a SCADA system measuring / recording turbidity to do this*)
- Need to prove pathogen inactivation being achieved is:
  - 4-log for viruses & 3-log for Giardia lamblia
  - Proof is based on **CT** calcs from daily reads on pH, tempersture, contact time, & chlorine residual (*Got SCADA data & a spreadsheet to make these calcs easy?*)

A Handy CT calculation spreadsheet:



A Google search for "EPA CT calculator" takes you directly to a download of this spreadsheet

More rules for unfiltered systems

- Records maintained for daily **CT** values calculated to show adequate crypto. & giardia "kill" must show the required **CT** in 11 of 12 months
- Redundancy in your disinfection system components
- RTCR still requires to test distribution system samples for Total Coliforms
- System shuts down if chlorine residual < 0.2 mg/L *(need a residual analyzer & SCADA recording of residual chlorine concentration for this)*
- Have a watershed control program in place to minimize contamination from Giardia & Cryptosporidium
- Effectively, UNFILTERED systems will need a Sanitary Survey performed by an independent company each year
- Also need to meet Disinfection By-product Rule requirements

QUIZ: In comparing Groundwater Rule (GWR) and Surface Water Treatment Rule disinfection requirements, the GWR doesn't require inactivation of Giardia lamblia or cryptosporidium cysts.

1. WHY?

2. In what situation might a groundwater supply require inactivation of crypto. cysts?

Disinfection By-product Rule

- Requires limiting concentrations of:
  - Sum of 4 Tri-halomethane (TTHM) compounds < 80 ug/L
  - Sum of 5 Haloacetic acid (HAA5) compounds < 60 ug/L
  - Other DBP compounds to include in rule <u>now being considered by EPA</u>
  - Compliance based on "Locational Running Annual Averages" (LRAA) for distribution sample points; 4 samples per year per sample point
    - Systems serving < 10,000 folks will just need 2 sample points w/4 samples per point per year
  - **Free Chlorine residual ≤ 4 mg/L**
- DBPs; An issue for water systems with high water age and if TOC in water > 1 mg/L prior to injecting the disinfectant

QUIZ: The sum of the 4 tri-halomethane (TTHM) compounds regulated by the DBP Rule includes:

- **A. Chloroform, bromodichloromethane, dibromochloromethane, & bromoacetic acid**

- **B. Chloroform, bromodichloromethane, dibromochloromethane, & bromate**

- **C. Chloroform, bromodichloromethane, dibromochloromethane, & bromoform**

Handy reference guides from EPA on all Da' Rules: **https://www.epa.gov/dwreginfo/drinking-water-rule-quick-reference-guides**

Filter Backwash Recycling Rule:

- Why recycle filter backwash water & other sidestreams?
  - Conserves raw water which may be scarce!
  - Saves on sewer use charges (assuming there is a sewer available)
- Notify NMED Drinking Water Bureau if you are going to start recycling backwash water or other silds handling sidestreams
- Quantify baseline operating data for your filters including:
  - Filter run times and typical filter backwash practices
  - Backwash flow rate ramp-up / ramp-down pattern & durations
- Make sure your plan for returning sidestreams won't upset water treatment operations
  - Q_{return} for "recycled water"; Need equalization? Need settling?

Filter Backwash Recycling Rule and other process sidestreams

- Thickener overflow is pretty clean (except when the thickener is overloaded)
- Sludge dewatering sidestreams can get "a little chunky", especially at start-up
- Think about any chemicals you use in these processes if you are going to recycle the sidestreams; Are they NSF 60 rated?

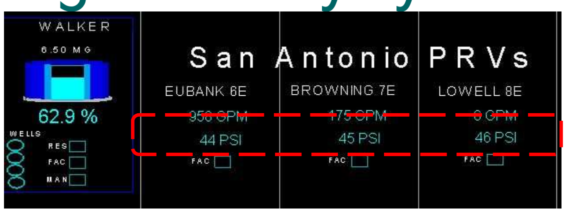
Trouble Consistently Meeting Da' Rules?

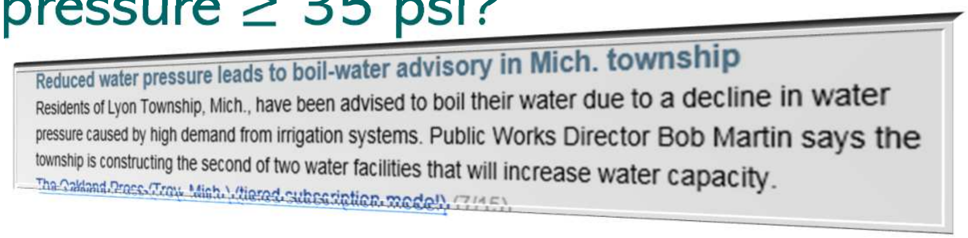
- ❑ Maybe join AWWA Partnership for Safe Water (PSW)-Treatment and/or PSW-Distribution
- ❑ A way to achieve compliance by optimizing your operations *(just more $$ for capital improvements may not be the best answer)*
- ❑ **MAIN GOAL** for PSW-Treatment : Get ≥ 95% of all your filtered water turbidity readings < 0.10 NTU! Each day, you collect & store(?) 96 CFE readings
- ❑ PSW-Treatment has 4 key steps:
  1. Sign up & commit; *Only $50/year for small systems!*
  2. Collect & submit filter turbidity data on PSW website each year
  3. Complete detailed self-assessment & submit to PSW program folks; *146 "easy" questions*
  4. Commit to making incremental improvements each year on those items you select to make better

Trouble Consistently Meeting Da' Rules?

- "My system buys all the water it distributes"

- AWWA PSW-Distribution has 3 main goals:
  - Line break frequency ≤ 15/100 miles of line?
  - Average monthly system pressure ≥ 35 psi?





Reduced water pressure leads to boil-water advisory in Mich. township

Residents of Lyon Township, Mich., have been advised to boil their water due to a decline in water pressure caused by high demand from irrigation systems. Public Works Director Bob Martin says the township is constructing the second of two water facilities that will increase water capacity.

The Oakland Press (Troy, Mich.) (tiered subscription model)

  - Free Cl residual maintained between 0.20 – 4.0 mg/L?
- Step 3 in AWWA PSW-Distribution: *just 85 "easy" questions*

What we are covering now:

- ❑Who is in class & types of water systems we run
- ❑What's in the raw water that customers don't want
- ❑SDWA Regulations on Surface Water Treatment = Da' Rules
- ❑Basic chemistry behind water treatment chemical reactions
  - ❑Alkalinity & pH
  - ❑Types of coagulants & other treatment chemcials

"Fun facts" about pH from chemistry

- Why do we care about this?
  - pH of water determines the species of alkalinity ion present in greatest concentration
  - Alkalinity impacts performance of coagulants we add to remove turbidity

- $pH = -\log_{10}[H^+]$; Also $pOH = -\log_{10}[OH^-]$
- $pH + pOH = 14$ for any concentration of $[H^+]$
- At neutral pH (pH = 7), concentration of $[H^+]$ = concentration of $[OH^-]$

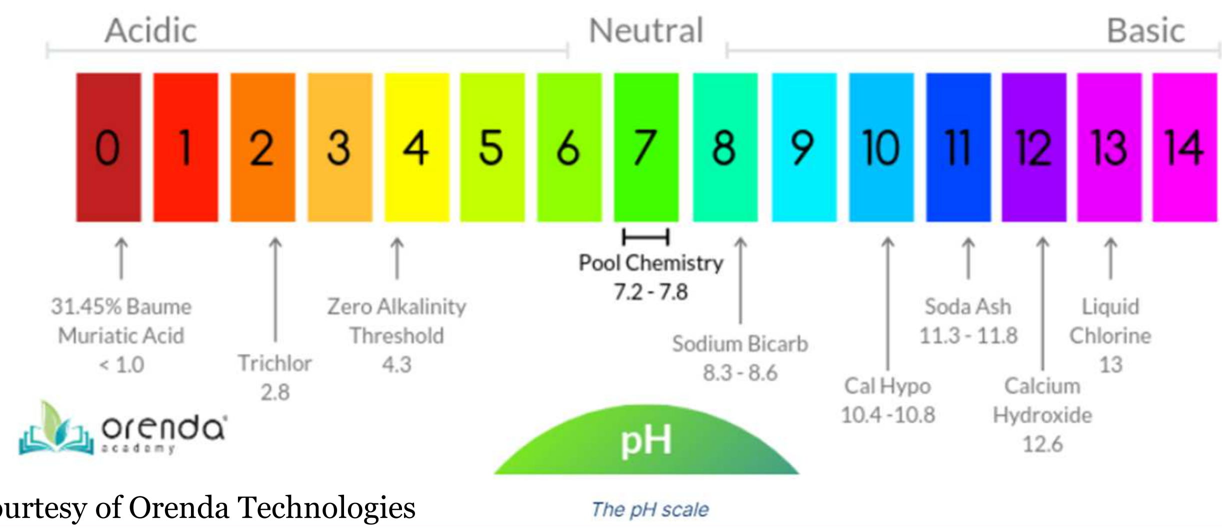


Figure courtesy of Orenda Technologies

QUIZ: At a pH = 10, what is the concentration ratio of OH^- ion to H^+ ion? (be ready to show your work and calculations)

- A. 6:1
- B. 100:1
- C. 10,000:1
- D. 1,000,000:1

Hints for solution: pH + pOH = 14

1. 14-(pH) = pOH
2. 14-10 = 4 =pOH
3. Remember that pH=10 is same as $\log_{10}[H^+] = -10$
4. "Clearing the logarithms": $[H^+] = 10^{-10}$ = 0.0000000001 (there are 9 zeroes in front of the 1)
5. pOH=4 is the same as $\log_{10}[OH^{-1}] = -4$
6. "Clearing the logarithms": $[OH^{-1}] = 10^{-4}$ = 0.0001 (3 zeroes in front of the 1)
7. Therefore, $[OH^{-1}] / [H^+]$ = ?????

The carbonate alkalinity system

- How carbonate ion gets into water and establishes an equilibrium:

$$[H_2O] + [CO_2] \Leftrightarrow [H_2CO_3]$$

water carbon dioxide carbonic acid

$$[H_2CO_3] \Leftrightarrow [H^{+1}] + [HCO_3^{-1}]$$

carbonic acid hydride ion bicarbonate ion

$$[HCO_3^{-1}] \Leftrightarrow [CO_3^{-2}] + [H^{+1}]$$

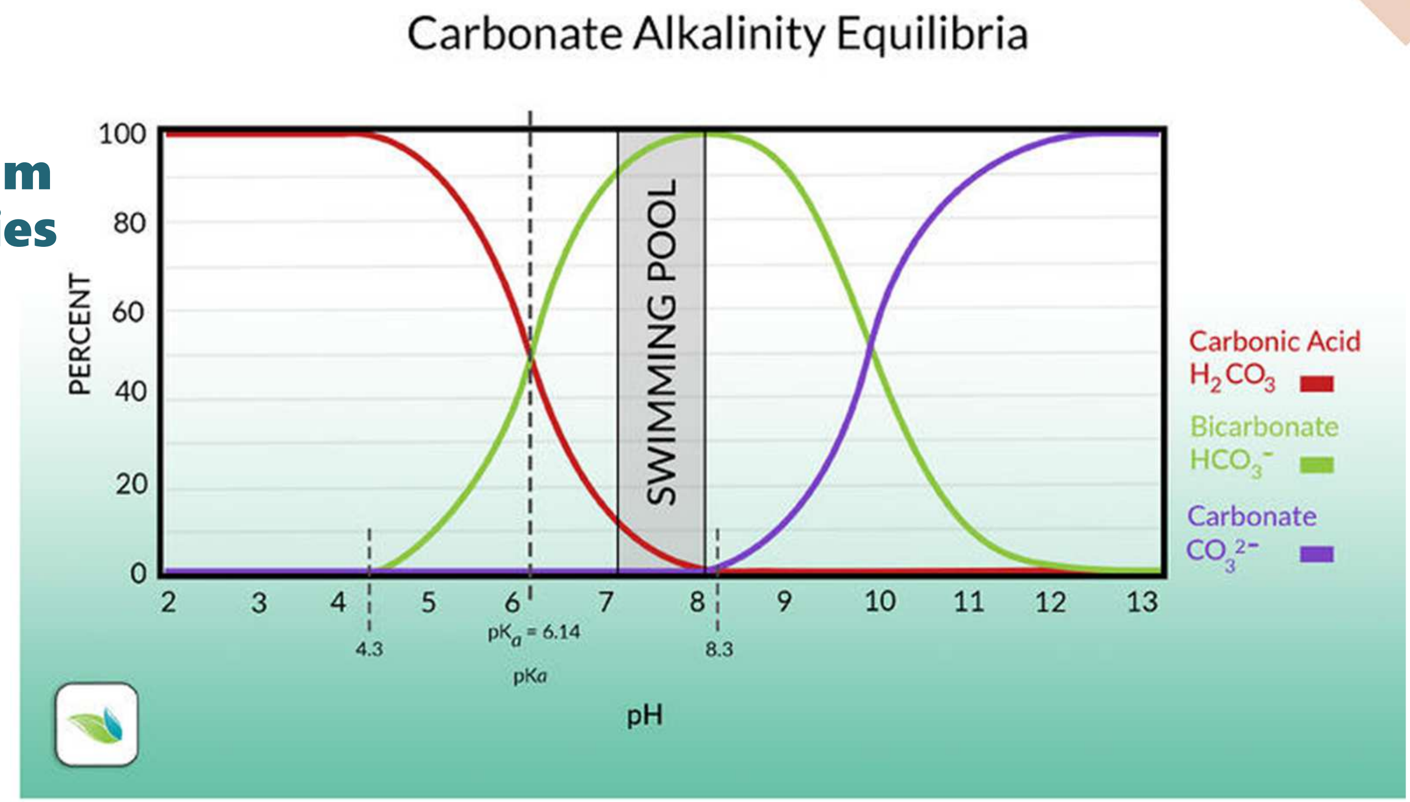
bicarbonate ion carbonate ion hydride ion

- The 2-way arrow means there is a 2-way equilibrium established in solution $\Leftrightarrow$

- **In these equations, the charges on each side and the counts of each atom must balance! Anyone remember the Law of Conservation of Mass?**

The carbonate alkalinity system

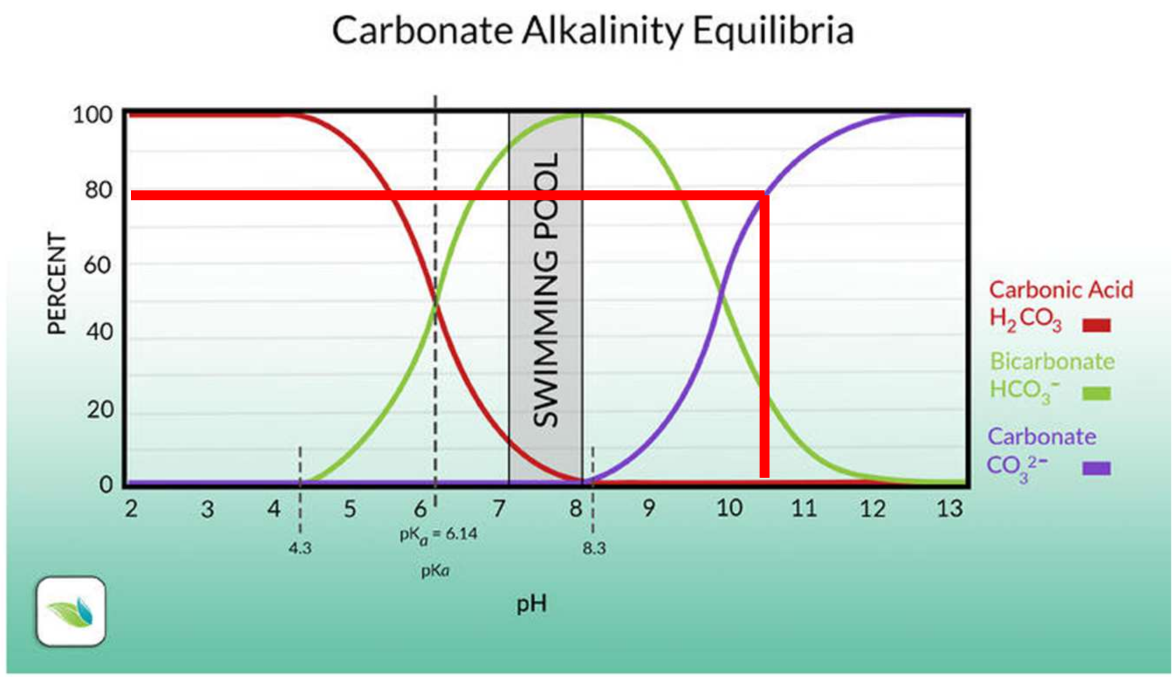
- **Useful chart for alkalinity equilibrium *<u>or</u>* which ionic species predominates in which pH range…**



Graph courtesy of Orenda Technologies

QUIZ: **An "efficient" pH for lime softening to remove calcium is 10.5 to 11. Using the equilibrium diagram, what species of alkalinity ion has the greatest concentration at this pH?**

- **A. H_2CO_3**
- **B. HCO_3^{-1}**
- **C. CO_3^{-2}**
- **D. H^{+1}**



Graph courtesy of Orenda Technologies

The carbonate alkalinity system and 2 VERY IMPORTANT EQUATIONS:

- **Equation for Total Alkalinity expressed in mg/L as $CaCO_3$:**

$$\text{TOTAL ALK.} = (HCO_3^{-1}) + (CO_3^{-2}) + (OH^{-1}) - (H^{+1}) \text{ mg/L as } CaCO_3$$

{Bicarbonate ion + Carbonate ion + Hydroxide ion – Hydride ion}

- **Equation for Total Alkalinity expressed in *milli-equivalents/Liter*:**

$$\text{TOTAL ALK.} = [HCO_3^{-1}] + 2*[CO_3^{-2}] + [OH^{-1}] - [H^{+1}] \text{ milli-equivs./Liter}$$

{Bicarbonate ion + Carbonate ion + Hydroxide ion – Hydride ion}

For typical pH ranges in surface water treatment, you can usually ignore the OH^{-1} & H^{+1} concentrations

The carbonate alkalinity system

- Useful table of facts for alkalinity and hardness ions:

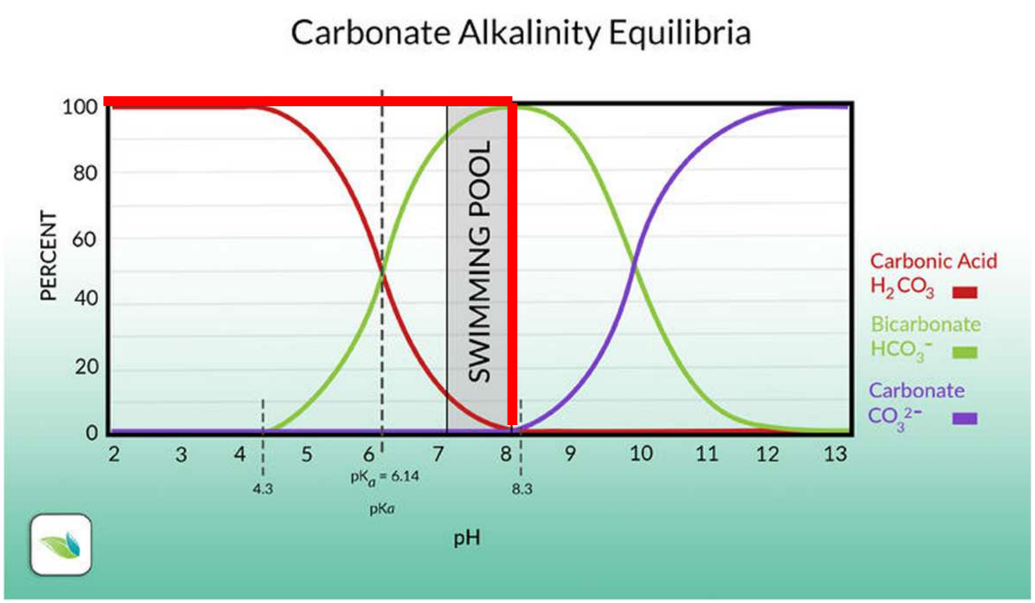
Ion name	Formula	Weight; mg/mole	Weight; milli-equivalent/mole	Conversion factor for $CaCO_3$ equivalent
Bicarbonate ion	HCO_3^{-1}	61	61	1.64
Carbonate ion	CO_3^{-2}	60	30	1.66
Carbonic acid	H_2CO_3	62	--	1.61
Hydroxide ion	OH^{-1}	17	17	5.88
Hydrogen ion	H^{+1}	1	1	100
Calcium ion	Ca^{+2}	40	20	2.5
Magnesium ion	Mg^{+2}	24	12	4.12
Calcium carbonate	$CaCO_3$	100	--	1
Calcium hydroxide	$Ca(OH)_2$	74	--	1.35

QUIZ: A raw water pH = 8 and has TOTAL ALK = 183 mg/L as $CaCO_3$. Which alkalinity ion has the greatest conc. at this pH & how many milli-equivalents per liter (meq/L) are present? Use the equilibrium diagram & "table of facts" data to assist w/calculations

A. All HCO_3^{-1} & 3 meq/L

B. All CO_3^{-2} & 6.1 meq/L

C. 50% CO_3^{-2} at 1.5 meq/L & 50% HCO_3^{-1} at 3.05 meq/L



Graph courtesy of Orenda Technologies

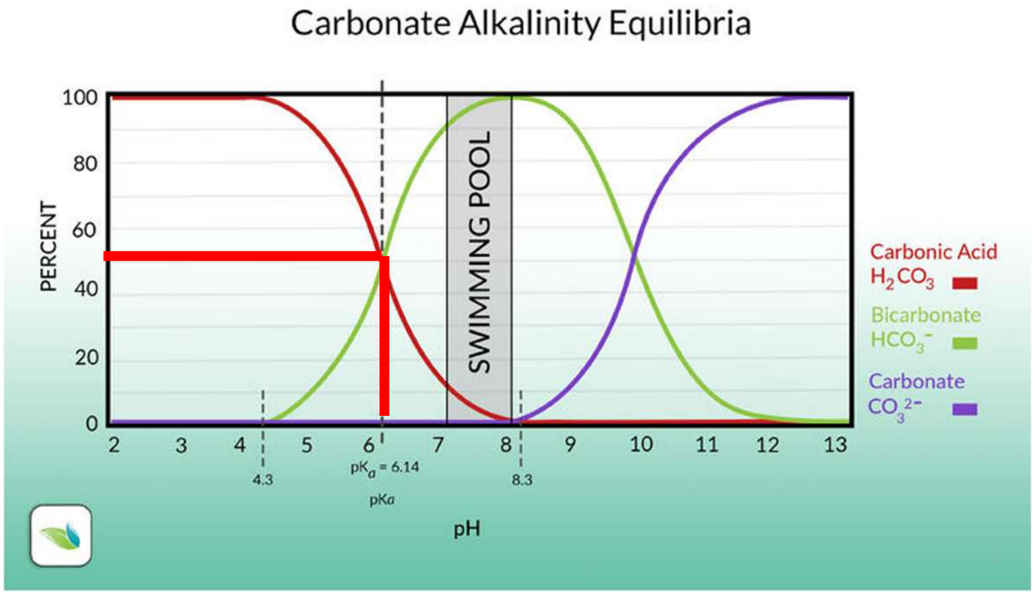
Hint: 61 mg of bicarb. ion = 1 milli-equiv. of bicarb. ion;
183 mg/L of bicarb. ion ÷ (61 mg of bicarb. / milli-equiv.) = ???

QUIZ: **If we add enough ferric chloride (an acidic coagulant) to drive the pH to 6.4, how much of the 183 mg/L of Total Alkalinity will still be present? Use the equilibrium diagram to graph your answer**

A. 50% or ≈ 91 mg/L as $CaCO_3$

B. 0%; It's all been converted to carbonic acid

C. 80% or ≈146 mg/L as $CaCO_3$



Hint: 183 mg/L of Total Alkalinity as $CaCO_3$ ÷ 2 = ???

Graph courtesy of Orenda Technologies

Common water treatment chemicals

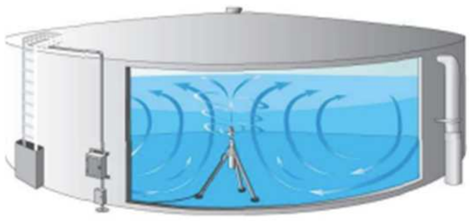
- Coagulants
  - Ferric chloride
  - Aluminum sulfate (filter alum)
  - Making a choice or change? Consider how you will manage the residuals from treatment; alum sludge management can be a pain
- pH adjusters
  - Take pH UP: Calcium hydroxide $Ca(OH)_2$ & Caustic soda NaOH; Stuff worth knowing
  - Take pH DOWN: Carbonic acid (made by dissolving CO_2 in water) and sulfuric acid
- Oxidizers
  - Ozone (O_3)
  - Potassium permanganate
  - Hydrogen peroxide H_2O_2
  - Various forms of chlorine
- Specialty chemicals
  - Polymers as coagulant aides or filter aides
  - Polyphosphate / orthophosphate blends for corrosion inhibition
  - Fluoride; added as liquid fluorosilicic acid ("silly acid") or made from sodium fluoride powder

Thoughts on storing your good quality product otherwise known as Reservoir Management

- ❑ Unlike fine wine, water stored in reservoirs "*doesn't*" improve with age"
  - ❑ Longer time for chlorine in solution to vanish; "Hey dude, what happened to my ≥ 0.2 mg/L residual?"
  - ❑ A possible issue for "Terminal Reservoirs" which are furthest from your system's entry point for finished water
  - ❑ Even a greater issue if finished water has TOC > 1 mg/L and it's summer, especially for systems serving treated surface water
    - ❑ Cranking up the treatment plant's chlorine dose can make matters worse and remember: There's a limit of 4 mg/L for your chlorine residual concentration!!
  - ❑ In summer, terminal reservoirs with low demand can get "stratified"
    - ❑ "Stratified" = topmost water layer gets warm and chlorine evaporates ☹ *Bye, bye free chlorine!*

Managing Reservoir Storage Issues

- Evaluate the reservoir storage age in your system
  - Get good data for customer water demands & "locations" of those demands in the system
  - Know enough about system line sizes to make a good skeleton water model and locations where water is entering
  - Perform some water system modeling to get those "water ages"
    - A favorite assignment for many water system engineers
- Consider benefits of adding mechanical mixers to tanks w/long storage times & where LRAAs are an issue; An easy way to break up stratification layers!!
  - Mixers for really remote tanks could be run off solar power
  - Maybe even add a ventilation system to headspace
    - You can drive the chloroform in TTHMs out of solution!
  - Maybe consider adding a remote station for adding chlorine disinfectant besides the one at the treatment plant



A PAX Impeller Mixer at work.

PAX mixer images courtesy of Cleanwater1

THANK YOU AND WISHING YOU SUCCESS IN YOUR UTILITY OPERATIONS CAREER!

Charlie Leder, PE
Hazen and Sawyer
505-236-3889; cleder@hazenandsawyer.com
NM Water Systems License, Level 4, #12411

Surface Water Treatment Part 2: Processes & Treatment Systems May 19, 2026

Charlie Leder, PE
Hazen and Sawyer
505-236-3889; cleder@hazenandsawyer.com
NM Water Systems License, Level 4, #12411

What we will cover in this class:

- ❑Who is in class & types of water systems we run
- ❑Review of key stuff from Part 1 Class
- ❑Surface water treatment and other water treatment processes
- ❑Systems & typical equipment set-ups for different kinds of water treatment

POLL: What NM Water Systems License Level do you hold?

- A. Level 1
- B. Level 2
- C. Level 3
- D. Level 4
- E. I don’t; I run a wastewater system!

POLL: Describe the water supply for your system

- A. Surface water
- B. Groundwater with 1-2 wells
- C. Groundwater with > 2 wells
- D. Groundwater that includes other treatment besides disinfection
- E. We purchase all water from a supplier (a consecutive system)

POLL: What is the class preference for working quiz questions and math problems? *(majority vote will rule!)*

- A. Individually
- B. Operator teams made of folks from same utility
- C. Teams made of the 3-5 persons closest to you

What we are now covering:

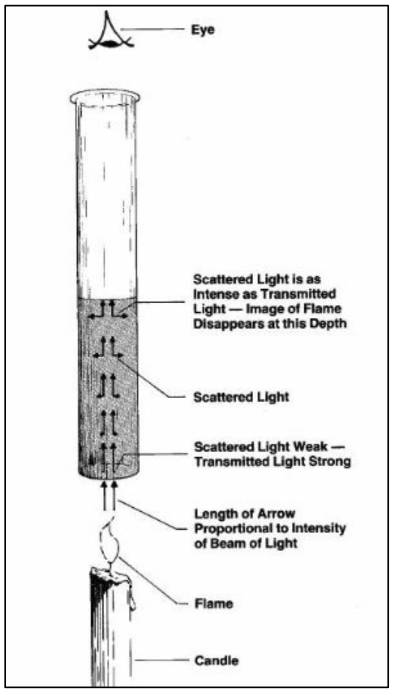
- ❑Who is in class & types of water systems we run
- ❑Review of key stuff from Part 1 Class
- ❑Surface water treatment and other water treatment processes
- ❑Systems & typical equipment set-ups for different kinds of water treatment

Review of key stuff from Part 1

- Types of stuff in the raw water that we don't want & why
- Important SDWA rules that impact treatment systems
- Basic chemistry regarding alkalinity and pH and their role in water treatment

Why is removing turbidity important?

- ❑ Customers don’t like cloudy or colored water!
- ❑ Turbidity interferes with disinfection!



Rules to remember for Surface Water Trt

- Revised Total Coliform Rule (RTCR)
  - It's really about distribution system water quality & the disinfection process
- Surface Water Treatment Rule or SWTR
- Long Term Phase 2 Enhanced SWTR or LT2ESWTR
- Filter Backwash Recycling Rule
- Disinfection By-Product (DBP) Rule

Filter Backwash Recycling Rule and rule for other process sidestreams

- Thickener overflow is pretty clean (*except when thickener is overloaded*)
- Sludge dewatering sidestreams can get "a little chunky", especially at start-up
- Think about chemicals you use in these processes; If you are going to recycle the sidestreams; Are they NSF 60 rated?

"Fun facts" about pH from chemistry

- ❑ Why do we care about this?
  - ❑pH of water impacts predominant species of alkalinity present
  - ❑Alkalinity impacts performance of coagulants we add to remove turbidity
- ❑ $pH = -\log_{10}[H^+]$; Also $pOH = -\log_{10}[OH^-]$
- ❑ $pH + pOH = 14$ for any concentration of $[H^+]$
- ❑ At neutral pH (pH = 7), concentration of $[H^+]$ = concentration of $[OH^-]$

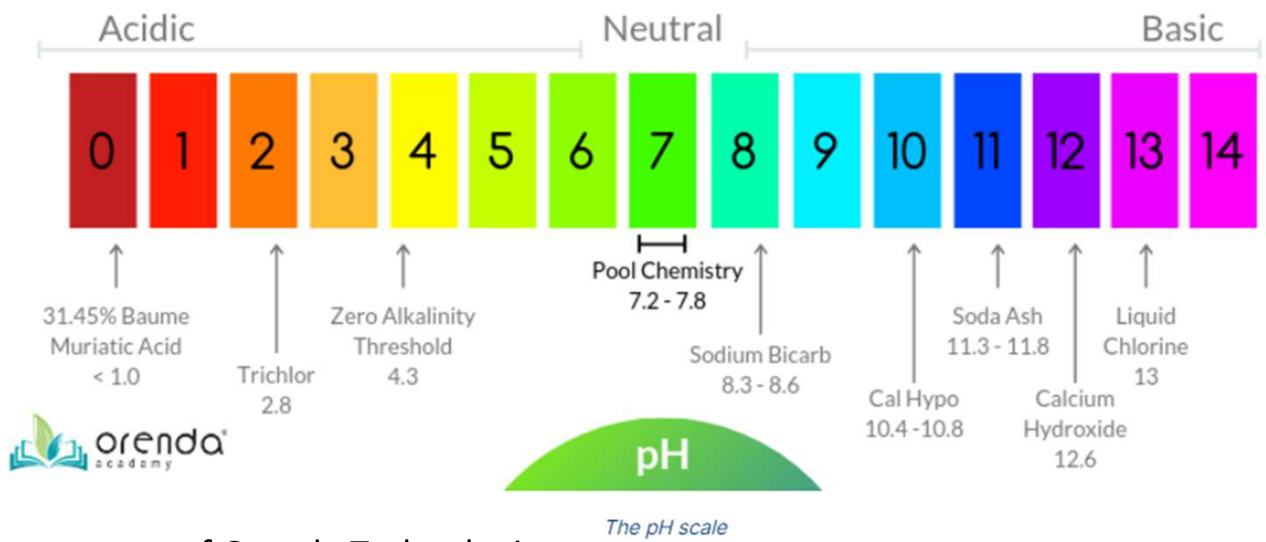
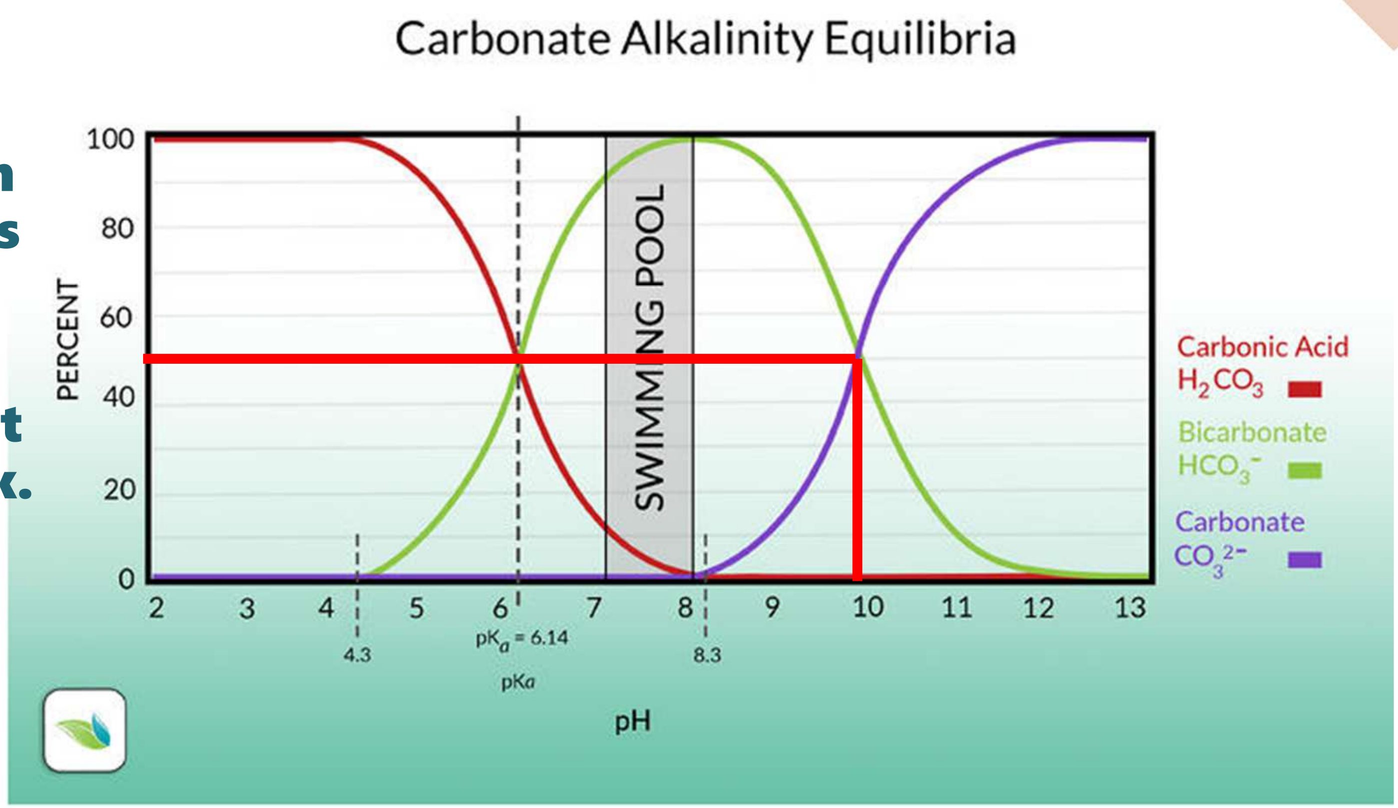


Figure courtesy of Orenda Technologies

The carbonate alkalinity system

- **Useful chart for alkalinity equilibrium *or* which ionic species predominates in which pH range…**
- **For pH ≈ 10; the chart says 50% of Total Alk. in solution will be HCO_3^{-1} and 50% will be CO_3^{-2}**



TOTAL ALK. = $(HCO_3^{-1}) + (CO_3^{-2}) + (OH^{-1}) - (H^{+1})$ in mg/L as $CaCO_3$

Graph courtesy of Orenda Technologies

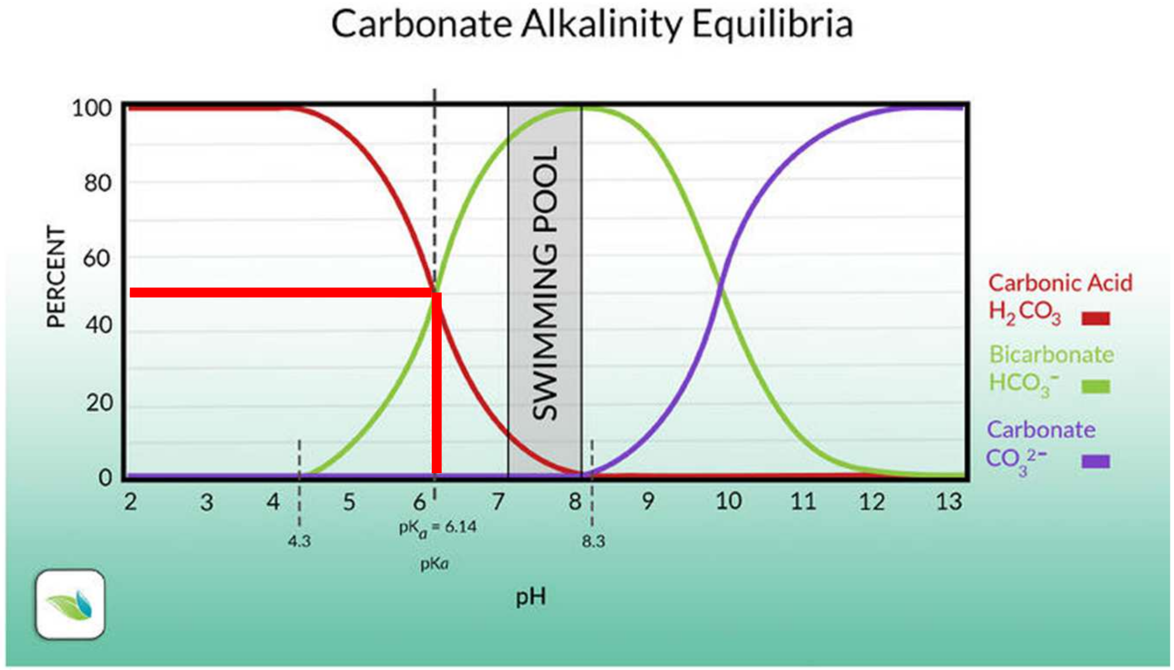
The carbonate alkalinity system

- Useful table of facts for alkalinity and hardness ions:

Ion name	Formula	Weight; mg/mole	Weight; milli-equivalent/mole	Conversion factor for $CaCO_3$ equivalent
Bicarbonate ion	HCO_3^{-1}	61	61	1.64
Carbonate ion	CO_3^{-2}	60	30	1.66
Carbonic acid	H_2CO_3	62	--	1.61
Hydroxide ion	OH^{-1}	17	17	5.88
Hydrogen ion	H^{+1}	1	1	100
Calcium ion	Ca^{+2}	40	20	2.5
Magnesium ion	Mg^{+2}	24	12	4.12
Calcium carbonate	$CaCO_3$	100	--	1
Calcium hydroxide	$Ca(OH)_2$	74	--	1.35

QUIZ: **The Clearwater Trt Plant coagulates w/alum to lower the pH to 6.4. What will be the predominant alkalinity ion present at this pH? (Hint: refer to the alkalinity equilibrium chart)**

- A. Equal amounts of HCO_3^{-1} and H_2CO_3
- B. HCO_3^{-1}
- C. CO_3^{-2}
- D. H_2CO_3



Graph courtesy of Orenda Technologies

QUIZ: Which elements found in well water are removed by water softening and together form Total Hardness?

- A. Calcium
- B. Magnesium
- C. Calcium & Manganese
- D. Sodium
- E. Magnesium & Calcium

What we are now covering:

- ❑Who is in class & types of water systems we run
- ❑Review of key stuff from Part 1 Class
- ❑Surface water treatment and other water treatment processes
- ❑Systems & typical equipment set-ups for different kinds of water treatment

Types of Water Treatment Processes

- *Why do we care about this?* Pick the right tool to remove those things we don't want in our water!

- Pre-sedimentation: A cheap way to remove surface water sands and silt

- Degasifying / aeration
  - Often seen in groundwater treatment with waters having odor issues or are slightly acidic
  - A cheap way to strip out dissolved gases like H_2S and $H_2CO_3^*$

- Rapid mixing, coagulation, & flocculation
  - Series of sequential steps to de-stabilize colloidal suspensions & form precipitates that settle

- Sedimentation; settle out the flocs that you formed
  You can't beat gravity (*most of the time*)

Types of Water Treatment Processes

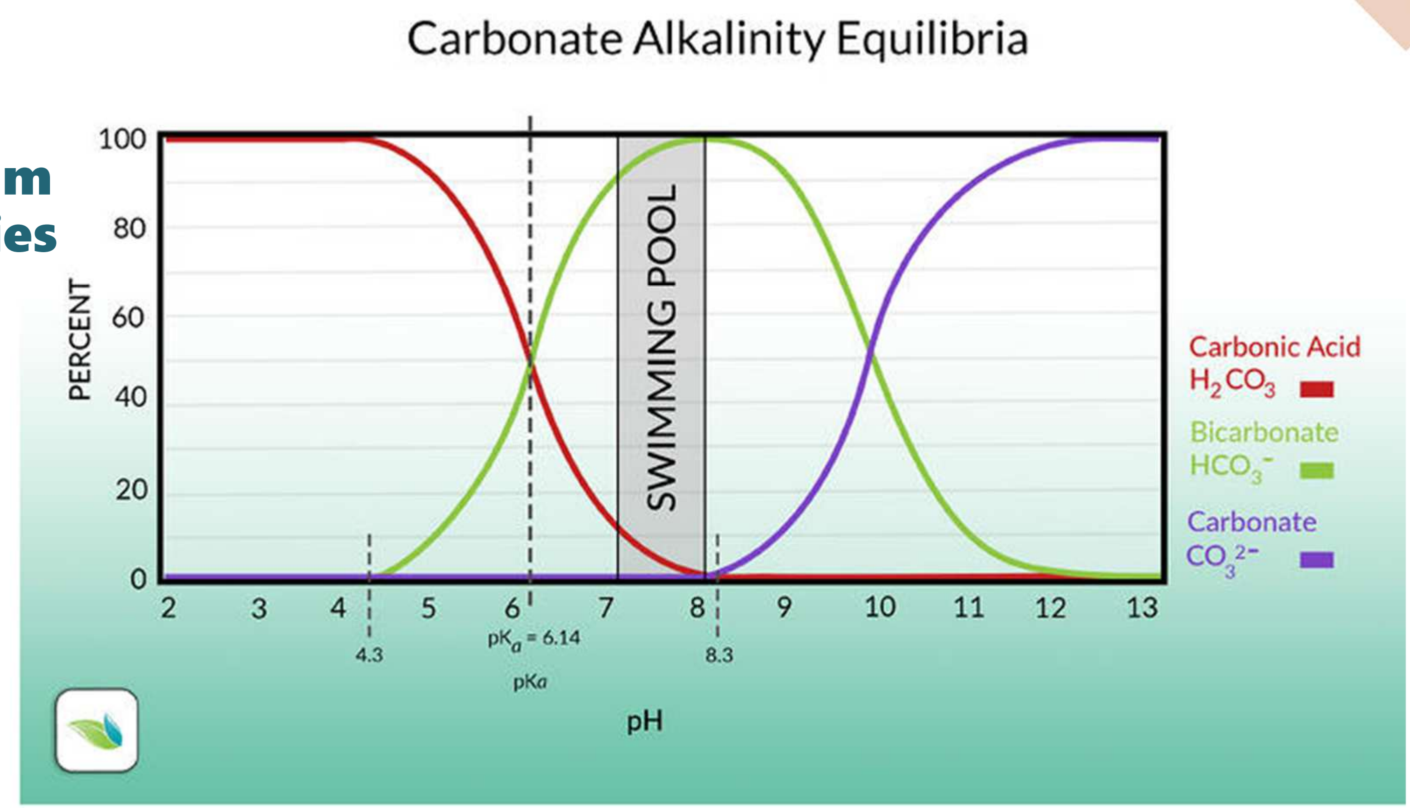
- Filtration; get rid of any leftover particles to achieve SDWA turbidity standards; Ways to filter include:
  - Granular media filtration after sedimentation; pretty standard
  - Direct filtration for clean raw waters; average turbidity < 10 NTU and "few upsets"
    - Coagulation goal for direct filtration: create a pin floc
  - Membrane filtration (ultrafiltration) for really clean raw waters
    - *Why try to make lots of floc if the water is already pretty clear?*
- Other variations / applications of filtration
  - Manganese greensand media for iron and manganese removal
  - After a lime softening process that removes hardness as $CaCO_3$ precipitates
- Disinfection to kill any leftover pathogens

Softening in Water Treatment

- Softening by lime precipitation to remove hardness ions; Ca + Mg
  - Why do this? Calcium and magnesium can precipitate out and plug equipment e.g., boilers, hot water heaters, & heat exchangers
  - Add hydroxide ion (OH^-) to raise pH, convert all alkalinity to CO_3^{-2}, and precipitate $CaCO_3$
    - Will precipitate Mg as $Mg(OH)_2$ *if* pH is raised ≥11
  - Concentrations of Ca, Mg, alkalinity, and sulfate all impact process
  - As more Mg is present as hardness, the precipitates become "fluffier"
  - If significant part of Ca hardness is non-carbonate i.e., SO_4^{-2} hardness, need to add soda ash (Na_2CO_3) to precipitate $CaCO_3$ in addition to lime; *it's just $Ca(OH)_2$ and only raises the pH*
  - Conventional lime softening usually generates massive quantities of sludge to manage ☹

The carbonate alkalinity system

- **Useful chart for alkalinity equilibrium *or* which ionic species predominates in which pH range…**



Graph courtesy of Orenda Technologies

Types of Water Treatment Processes

- Softening by ion exchange; "Hey Culligan man…"
  - Simply swapping calcium ions for sodium ions on a resin bed
    - Sodium ions added to the product water; Calcium sticks to the resin
    - Adding sodium to the water is not always a good thing!
  - Periodically regenerate the resin bed with saturated brine solution
    - Suggestion: Use softened water to prepare the saturated brine!
  - Not usually done for entire public water supply but may be critical for make-up water used in the treatment process e.g., on-site generated hypochlorite (NaOCl) used for disinfection
  - Disposal of the brine regenerant may be an issue for sewer system

Other Water Treatment Processes

- Desalination using high pressure membranes; salt and ion removal using nanofiltration and/or reverse osmosis
- Desalination using electrodialysis; motive force for ion separation is electrical charge applied to membranes
- Absorption processes
  - Arsenic absorption using a proprietary iron media e.g., Bayoxide$_{33}$
    - Media is used one time & then disposed (If it passes the TCLP test!)
  - Specialty ion exchange medias for exotic stuff: long-chain PFAS
  - Activated carbon for removing organics
    - Anyone want to handle used, PFAS-laced activated carbon (or spent IX media)?

Final Types of Treatment Processes

- pH adjustment to stabilize water; a MUST after:
  - Lime softening; Continued $CaCO_3$ precip. will gum up the filter bed!
  - Enhanced coagulation; *pH of water is too acidic to put in system!*
  - Desalination; Need to replace carbonate ions else permeate will "attack" carbonate films that form on distribution system waterlines
- Fluoridation to promote dental health in population served
  - Don't promise more than the technology can deliver
  - Recommended 0.7 mg/L dose will be met +/- 0.1 mg/L, at best!
- Specialty chemical additives e.g. polyphosphate / orthophosphate blends to balance corrosion / precipitation reactions in distribution system

QUIZ: Adding lime slurry to filtered & disinfected finished water will…

- A. Only increase water pH
- B. Only increase hardness
- C. Increase both water pH and hardness
- D. Could cause cloudiness in the water
- E. Both C and D

What we are now covering:

- ❑Who is in class & types of water systems we run
- ❑Review of key stuff from Part 1 Class
- ❑Surface water treatment and other water treatment processes
- ❑Systems & typical equipment set-ups for different kinds of water treatment; *Part 3 at 1PM will cover the newest stuff* ☺

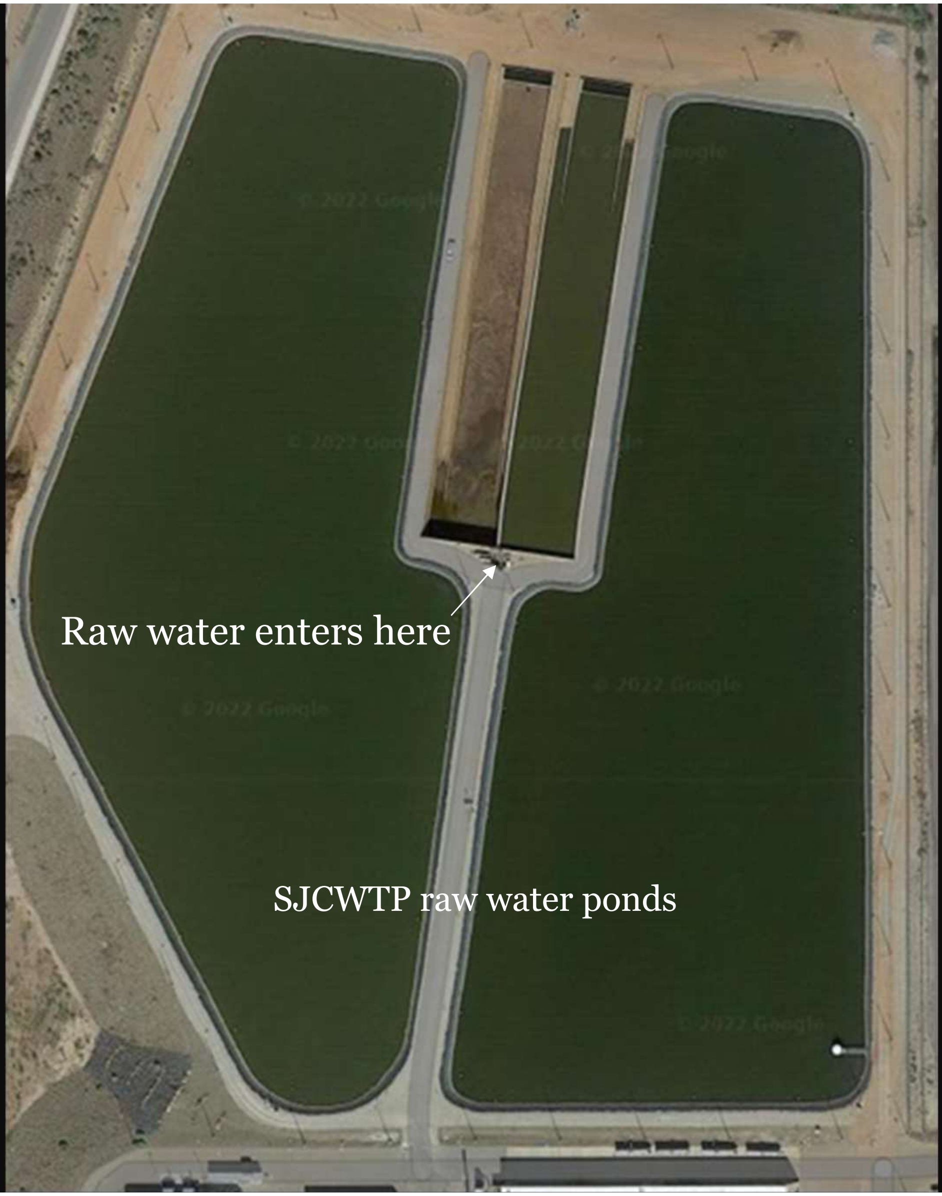
Conventional trt. scheme for "turbid" water

- Treatment goals: get rid of settleable & suspended sediments and pathogens in raw water
- How?

1. Start with a **BIG** pond to store diverted water & remove settleables
2. Add chemicals to <u>destabilize suspended colloidal solids</u> so they stick together & settle: Use rapid mixing, coagulation, and flocculation to get something that will gravity settle
3. Gravity settle the flocs; Target clarity is 2-4 NTU for settled water
4. Filter out remaining solids to achieve ≤ 0.3 NTU for filtered water turbidity in 95% of all filter cell turbidity readings
5. Disinfect the water to kill remaining pathogens

Step 1: Gravity Settling in a **BIG** pond

- Our goal: get rid of settleable stuff by simple gravity settling
- Why?
  - 1. Keep the heavy stuff from plugging downstream equipment
  - 2. Provide a buffer for when raw water turbidity spikes
- How big? As big as available land area will allow the pond to be
- Have a plan for eventually removing the stuff that settles in the pond *(Ask ABCWUA how their plan worked)*



QUIZ: Suspended colloidal sediments…

- A. Are electrically charged particles and repel each other
- B. Are stable in solution & will not settle out by gravity
- C. May be destabilized if particle surface charges are neutralized
- D. All of the above

Step 2: Destabilize Suspended Colloidal Stuff

- Includes both organic and inorganic colloidal material
- How? Add a chemical(s) to neutralize surface charges on particles and under right conditions, it will glue them together and gravity settle
- Chemical reaction for a ferric salt coagulant; Remember: ***It's a 1-way street!***

$$Fe^{+3} + 3HCO_3^{-1} + 3H_2O \Longrightarrow Fe(OH)_3 \downarrow + 3H_2CO_3$$

- First: Add lots of mixing energy to quickly disperse the chemicals throughout the bulk solution; How much energy?
  - Evaluate with "G", the mean velocity gradient ≈ energy input to mix chamber
  - For mechanical mixers used in rapid mixing, typical "G" is 500-600 $seconds^{-1}$

Step 2: Destabilize Suspended Colloidal Stuff

- Includes both organic and inorganic colloidal material
- How? We already added a chemical(s) to neutralize surface charges on particles and under right conditions, will glue them together and gravity settle

- Chemical reaction for a ferric chloride coagulant: Remember: ***<u>It's a 1-way street!</u>***

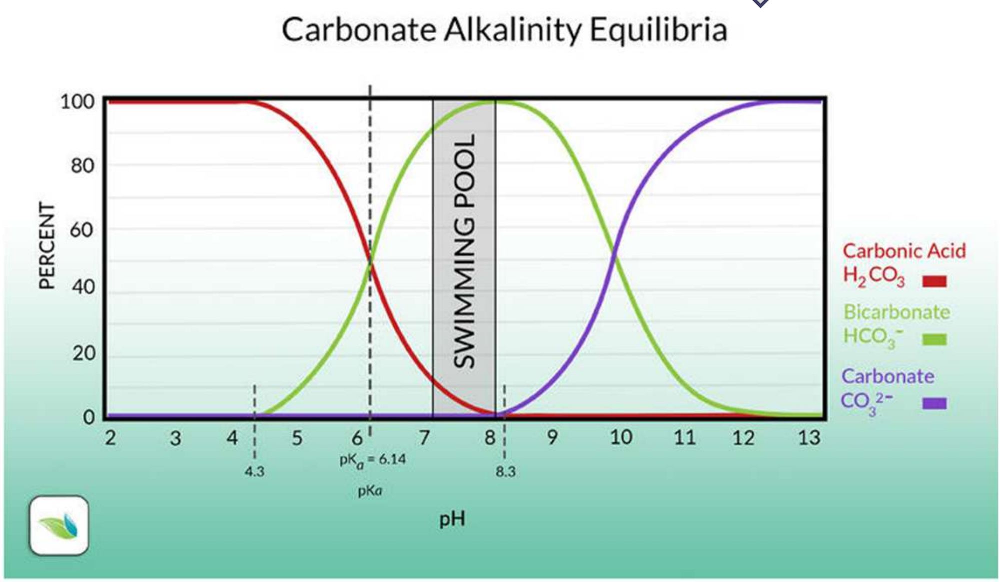
$$Fe^{+3} + 3HCO_3^{-1} + 3H_2O \Longrightarrow Fe(OH)_3 \downarrow + 3H_2CO_3$$

- Second: Use *GENTLE* mixing to "coagulate the *<u>destabilized</u>* particles" i.e., glue them together and grow flocs that will settle later
  - "G" values for gentle mechanical mixing: 25 – 75 $seconds^{-1}$
  - Typically, 2 or 3 mixing chambers in series w/slow turning mixers; Speed adjustment on mixers is a good thing, especially if your raw water has seasonal temperature changes!

QUIZ: In the sample equation for ferric chloride addition, what are the expected outcomes?

- A. HCO_3^{-1} ion in solution is converted to dissolved carbonic acid (H_2CO_3) and the pH will drop
- B. HCO_3^{-1} ion in solution is being converted to CO_3^{-2} ion and the pH will rise
- C. Ferric hydroxide $Fe(OH)_3$ will precipitate & settle (quickly)
- D. A and C

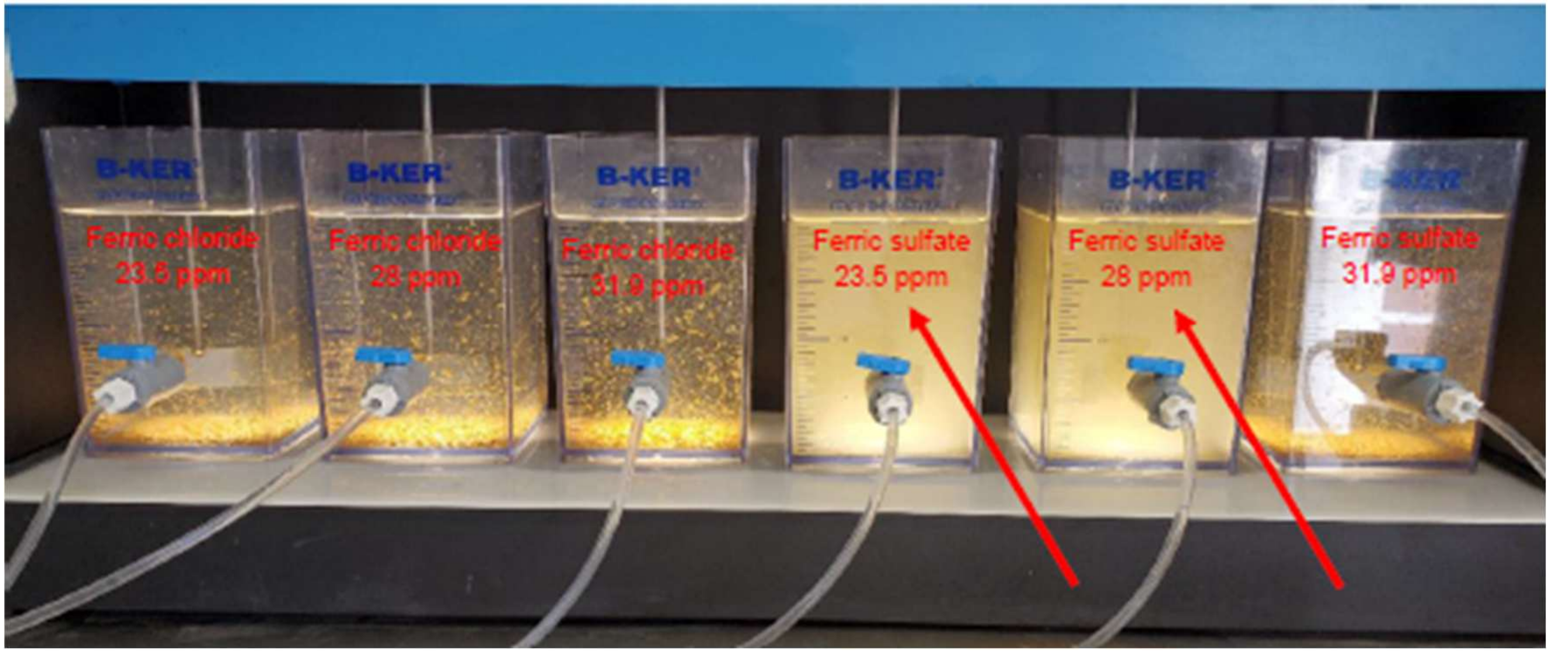
$$Fe^{+3} + 3HCO_3^{-1} + 3H_2O \longrightarrow Fe(OH)_3\downarrow + 3H_2CO_3$$



Graph courtesy of Orenda Technologies

Step 2: Destabilize Suspended Colloidal Stuff

- A well settling floc looks like the stuff in the 3 jars at left:



- Use jar tests to experiment & fine tune coagulant types and doses

Step 3: Put gravity to work & settle the flocs

- A big empty tank for gravity settling
- Turbidity target for settled, “floc free” water: 1-3 NTU
- Settling is proportional to “rise rate” in the clarifier
- For a fixed tank volume; more surface area reduces rise rate & gives better settling
- Typical rise rates for conventional clarifiers: 300 – 900 gpd / $foot^2$
- Nominal hydraulic detention time ≈ 2 hours
- Other components of a conventional clarifier
  - Inclined plates or tube modules that increase net surface area
  - Scraper system to push sludge to a hopper & drain point
  - Effluent launders / weirs to control flow of clarified effluent

Step 4: Filter out remaining solids

- Turbidity target for filtrate: ≤ 0.3 NTU in 95% of all CFE readings
  - Readings taken every 15 minutes in filtrate from each filter cell
- Main components of a typical granular media filter:
  - The media bed
  - Underdrain to support the media, collect filtrate, & distribute wash water (& maybe scouring air) used to clean the filter media
  - Troughs to collect dirty filter wash water
  - Valves & piping to regulate flow of water into / from the filter
  - Instruments to monitor filtrate turbidity, filtrate flow, and headloss (pressure drop) thru filter
- Treatment plants typically have 4 or more equal size filter cells

Filter media types:

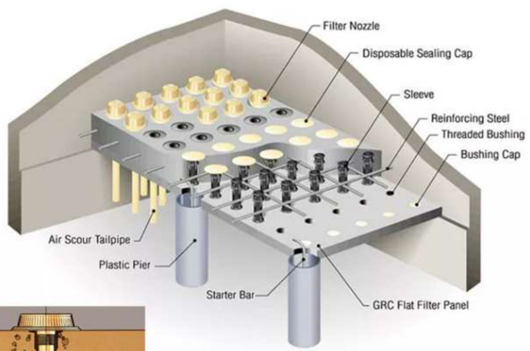
Type	Component	Depth	Media size, mm	Specific gravity	Comments
Dual media	Anthracite coal	24”	1.0-1.2	1.6	Little mixing between sand & anthracite layers after backwash
	Silica sand	12”	0.45-.55	2.6	
Mixed media	Anthracite coal	24”	1.0-1.2	1.6	3 media layers intermix (anthracite w/sand & sand w/garnet) following backwash
	Silica sand	9”	0.45-.55	2.6	
	Garnet	3”	0.20	4.0	
Dual media w/activated carbon	Activated carbon	60”	1.0-1.2	1.4	Activated carbon promotes biological activity in the media which helps absorb organics that cause taste & odors
	Silica sand	12”	045-.55	2.6	

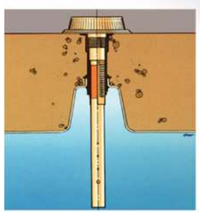
Deep bed dual media filters sometimes use anthracite instead of activated carbon e.g., Denver Water’s new Northern WTP

- Nominal filter loading rates: 3-5 gpm/square foot of filter bed area
- Clean the media w/combination of scouring air and water backwash

Filter components for Step 4:

Popular types of filter underdrains in use today:





Nozzle type
SJCWTP

Plastic block
City of Las Vegas

Folded slotted stainless steel
Raton Water Works

- Purpose: support the media w/out needing any gravel & collect clean filtrate
  - Eliminating support gravel layer allows for deeper media beds
- Also: Uniformly distribute scouring air & backwash water during cleanings

Step 4A: Cleaning a dirty filter cell; Parts 1-4

- Clean a cell when 1) it gets plugged (high headloss), 2) after ≈ 96 hrs of time in service, or 3) turbidity breakthrough ☹
- Cell cleaning involves the following general 9-part sequence :
  1. Drain down the cell till 2-3 feet of water left above media
  2. Turn on air compressor for scouring air that gives a high energy scrub to remove particles trapped in the media ≈ 5 minutes
  3. Turn on filter backwash water supply at rate of 5 gpm/ft^2 while scouring air flow stays on; Start flushing out the loosened debris
  4. Turn off scour air after 5 minutes & slowly begin to increase wash water flow rate to 20 gpm/ft2 ; Pick a rate of flow increase and Q that gives "optimal results" (this will change with water temperature)

Step 4A: Clean a dirty filter cell; Parts 5-9

5. Maintain wash rate at 20 gpm/ft^2(?) until wash water turbidity < 30 NTU
6. Slowly ramp down wash water flow to 0 gpm
7. Filter is ready to receive clarifier effluent again
8. Allow filter to "ripen"; Send initial filtrate flow to waste until its NTU < 0.3
9. Once the filter media has "ripened", return the filter cell to service

- ❑ Most WTPs today have control systems that automatically open and close valves on the filters to achieve this 9-part sequence ☺
- ❑ Operators *like you* find the best combination of wash flow rates & step durations to achieve "effective filter cleaning"; *More on this in Part 3 Class*

QUIZ: The Clearwater WTP treats 12 MGD using 6 filter cells that give a total of 1800 SF of surface area. With all cells in service, this plant runs its filters at:

- A. 2.31 gpm/SF
- B. 4.62 gpm/SF
- C. 6.63 gpm/SF

Solution Hints:

1. gpm/SF = gallons per minute per square foot of filter area
2. A 12 MGD flow = ??? Gallons per minute
3. Filter loading rate in gpm/SF = Q/A

QUIZ: In the last example, the filter rate increases to what rate when one of the 6 cells is removed from service for cleaning?

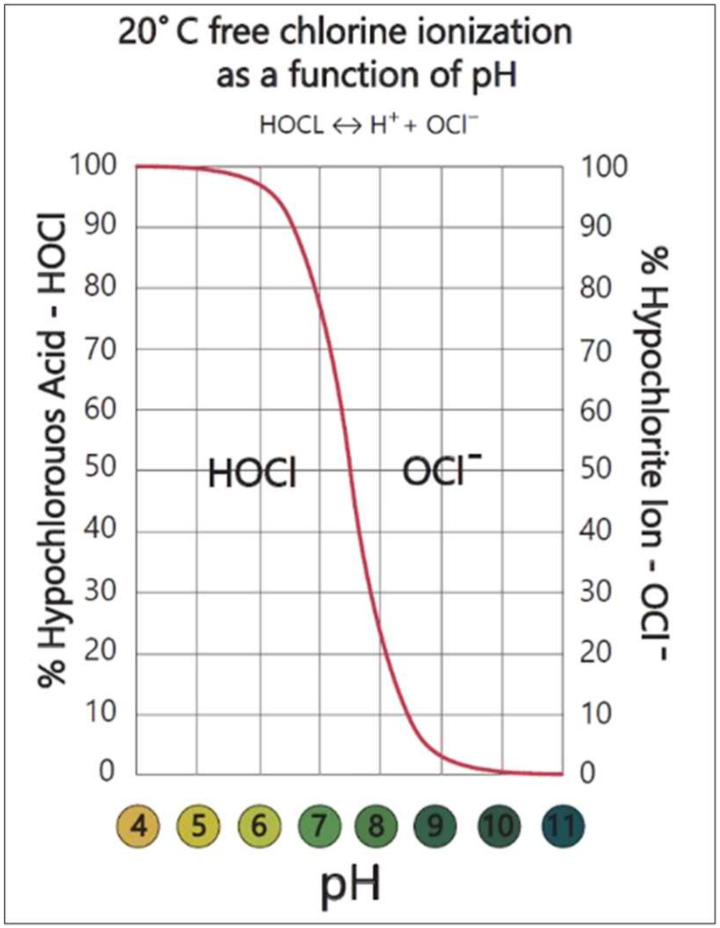
- **A. 5.56 gpm/SF**
- **B. 5.84 gpm/SF**
- **C. 6.17 gpm/SF**

Solution Hints:

1. The old filter loading rate in gpm/SF = ???
2. The flow rate through the plant stays the same
3. Filter area per *each* of 6 filter cells = ???
4. With 5 cells in service, the total filter area remaining in service = ??
5. The new filter loading rate is ??

Step 5: Disinfect to kill remaining pathogens

- Hypochlorous acid (HOCl) <u>is the workhorse</u>!
  - Much stronger disinfectant than hypochlorite ion (OCl^{-1})
- It's effective in waters w/pH range of 6-8.5
- Higher dose is required in more alkaline waters as hypochlorite ion (OCl^{-1}) becomes the more prevalent compound in solution:



Step 5: Disinfect to kill remaining pathogens

- Free chlorine residual measures the combined concentration of HOCl, OCl^-, and any undissolved gaseous chlorine (very little is present at typical doses for disinfection)
- Total chlorine residual also includes chloramines (if present; these are monochloramine, dichloramine, & trichloramine)
- Testing for chlorine residual
  - DPD test & the color wheel (test for Total & Free Chlorine)
    DPD = Diethyl-p-Phenylene-Diemine
  - Amperometric titration; *A good method for collecting real-time data 24/7/365*
  - Colorimeters replace the color wheel

Stuff to remember about disinfection w/Cl:

- Warmer water temperature will increase the reactivity of all chlorine-based disinfectants ***BUT*** also helps drive them out of solution faster
  - Opposite happens w/colder water temps

- Organic substances in the water will consume some of the chlorine and form organo-chlorine compounds e.g. THMs & other DPBs

- Often seen when disinfecting waters w/TOC content >1 mg/L

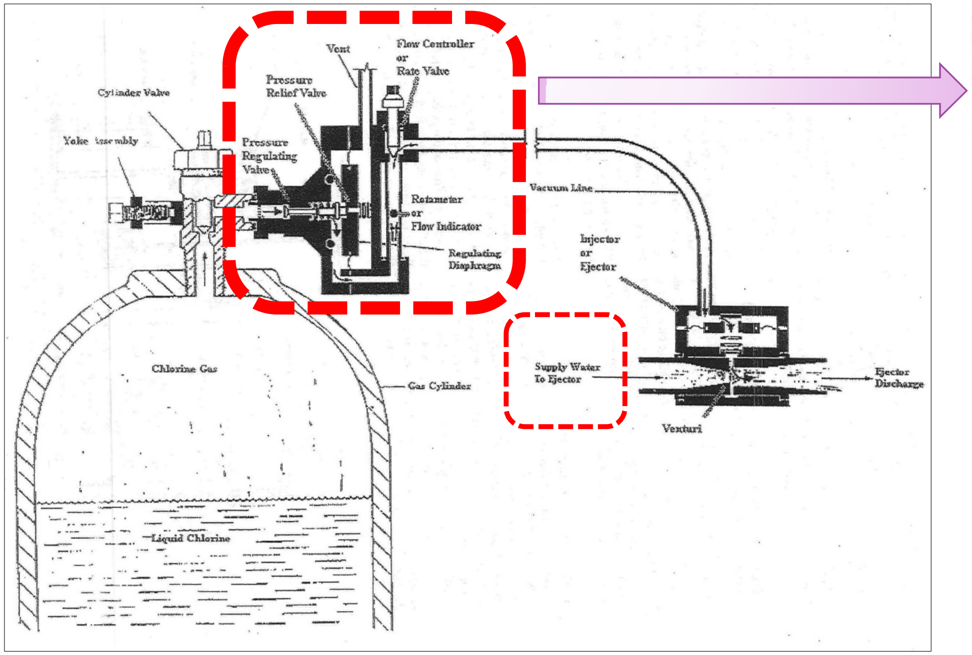
Disinfection w/chloramines; interesting stuff:

- Weakest & slowest reaction time of all chlorine-based disinfectants; required CT for chloramine disinfection much higher than w/free chlorine
- Also the disinfectant that's least likely to form DBPs
- Key concern in controlling chloramination reactions for disinfection systems: adding too much ammonia
  - Free ammonia becomes food for bacterial films growing in your distribution system pipes
- If you have an inter-connect agreement with another system for emergency water supply and you chloraminate the water in your system but they use free chlorine for disinfection…

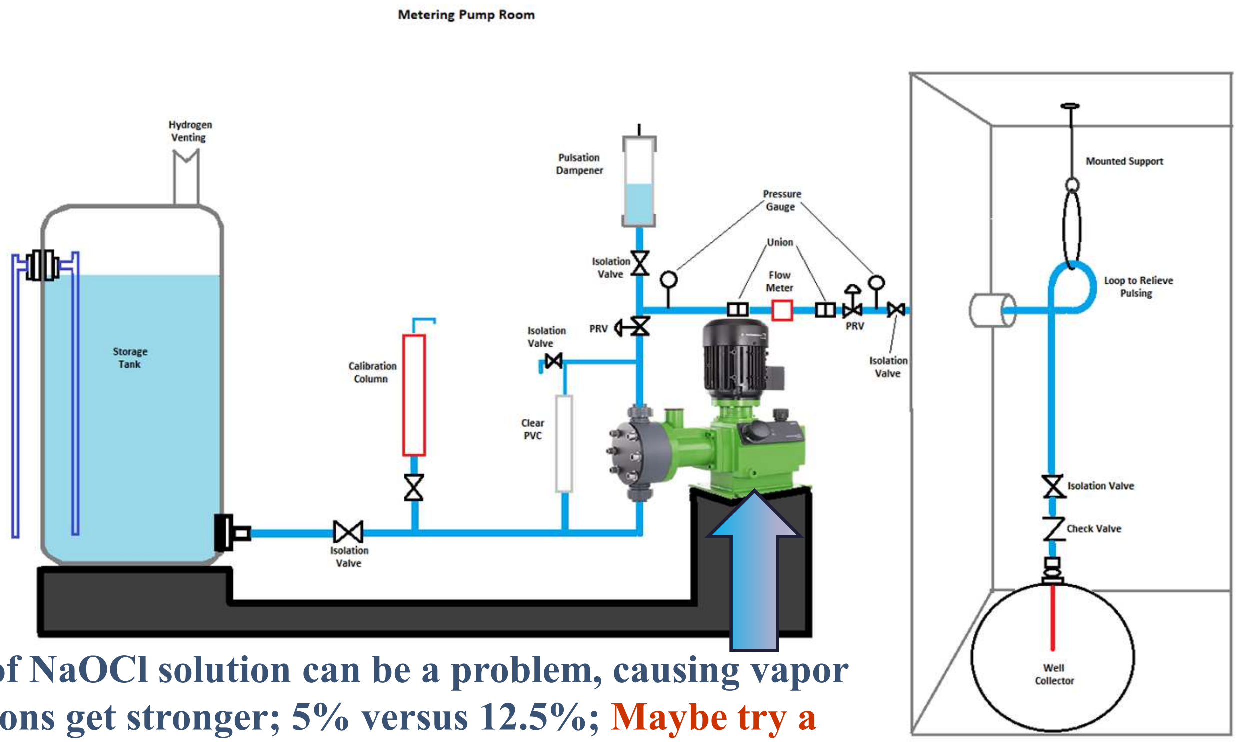
POLL: What chemical does your system use for disinfection?

- A. Chlorine gas
- B. Liquid sodium hypochlorite (NaOCl or bleach)
- C. On-site generated hypochlorite (HOCl)
- D. High Test Hypochlorite (HTH) tablets disinfection
- E. Chloramines

Typical set-up for chlorine gas feed

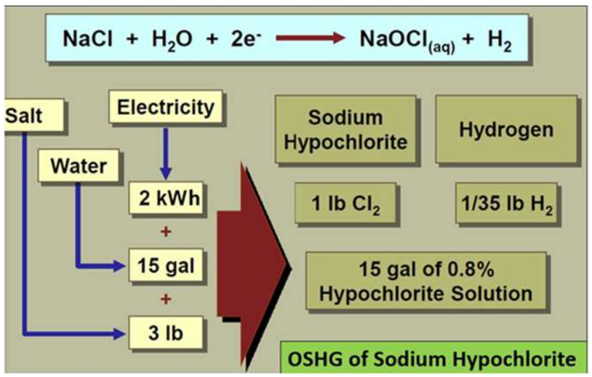


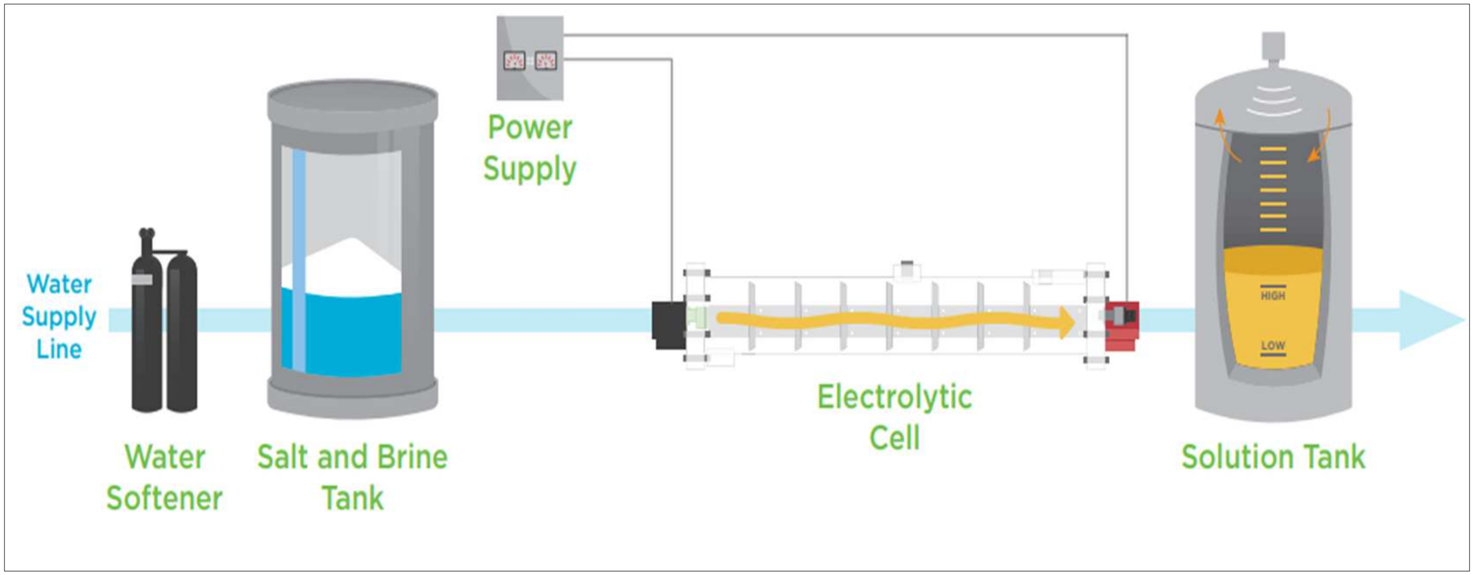
Typical set-up for liquid NaOCl feed



Off-gassing of NaOCl solution can be a problem, causing vapor lock as solutions get stronger; 5% versus 12.5%; Maybe try a peristaltic pump instead of a diaphragm pump?

Typical System for On-site Generated HOCl Solution





OSHG systems generate 0.8% strength HOCl

QUIZ: Comparing typical pump set-ups for feeding 10% bleach vs on-site generated 0.8% HOCl, to feed the same chlorine dose, the metering pump...

- A. Gets smaller if feeding 12.5% bleach
- B. Gets bigger if feeding 12.5% bleach
- C. Stays the same; there would be no change in pump size

Need Continuous Measurement of Cl Residual?

- Example of a flow-through device w/*no waste discharge*
- Detects HOCl strength using amperometric titration
- Compensates for pH
- Calibrated w/DPD method

THANK YOU AND WISHING YOU SUCCESS IN YOUR UTILITY OPERATIONS CAREER!

Charlie Leder, PE
Hazen and Sawyer
505-236-3889; cleder@hazenandsawyer.com
NM Water Systems License, Level 4, #12411

Surface Water Treatment Part 3
May 19, 2026

- ❑ Advanced & intensified treatment processes
- ❑ Water Treatment Residuals Management
- ❑ Measuring & Optimizing Treatment System Performance

Charlie Leder, PE
Hazen and Sawyer
505-236-3889; cleder@hazenandsawyer.com
NM Water Systems License, Level 4, #12411

What we will cover in this class:

- ❑Who is in class & types of water systems we run
- ❑Review of key stuff from Part 2 Class
- ❑ Intensified water treatment process; doing more treatment in less space and doing it faster
- ❑Managing water treatment residuals
- ❑ How to measure & optimize performance of water treatment processes taught in this class
- ❑ Fun with word problems & water treatment math

POLL: What NM Water Systems License Level do you hold?

- A. Level 1
- B. Level 2
- C. Level 3
- D. Level 4
- E. I don't; I run a wastewater system!

POLL: How many people does your system serve?

- A. < 500
- B. 500 – 3,000
- C. 3,001 – 10,000
- D. 10,001 – 50,000
- E. > 50,000

POLL: What is the class preference for working quiz questions and math problems? *(majority vote will rule!)*

- A. Individually
- B. Operator teams made of folks from same utility
- C. Teams made of the 3-5 persons closest to you

What we are covering now:

- ❑Who is in class & types of water systems we run
- ❑Review of key stuff from Part 2 Class
- ❑ Intensified water treatment processes; doing more treatment in less space and doing it faster
- ❑Managing water treatment residuals
- ❑ How to measure & optimize performance of water trt. processes taught in this class
- ❑ *Fun with word problems & water treatment math*

Types of Water Treatment Processes

- Why do we care about this? Pick the right tool to get rid of things we don't want in our water to keep it safe!

- Pre-sedimentation: A cheap way to remove surface water sands and silt

- Degasifying / aeration
  - Often seen in groundwater treatment with waters having odor issues or w/slightly acidic pH
  - Cheap way to strip dissolved gases like H_2S and CO_2; Stripping the CO_2 means less alkalinity

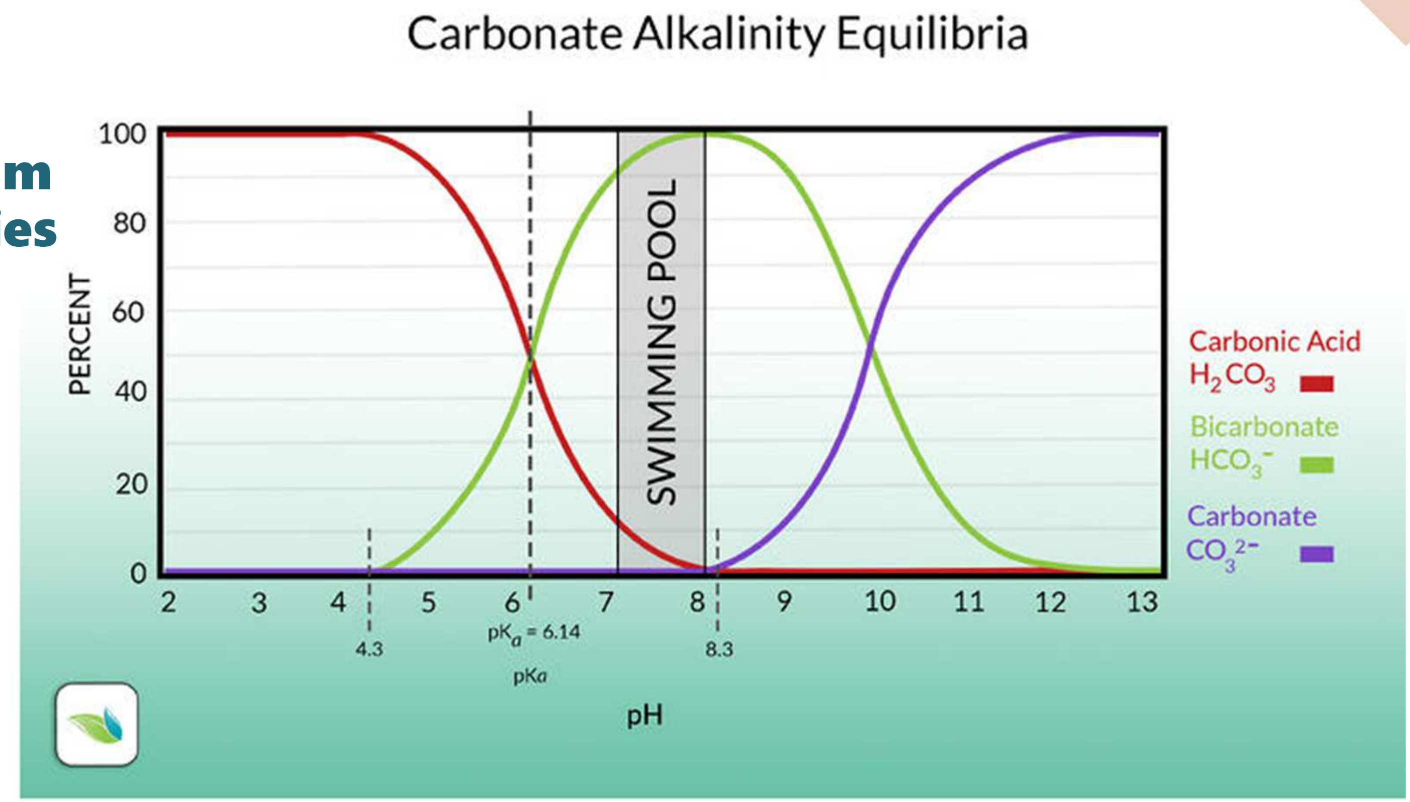
- Rapid mixing, coagulation, & flocculation
  - Series of sequential steps to add the RIGHT chemicals to de-stabilize colloidal suspensions & form precipitates that settle

- Sedimentation; settle out the formed flocs; you can't beat gravity (most of the time)

- Softening processes for hard water (easier *IF* enough carbonate alkalinity is present)

The carbonate alkalinity system

- **Useful chart for alkalinity equilibrium _or_ which ionic species predominates in which pH range…**



Graph courtesy of Orenda Technologies

Types of Water Treatment Processes

- Filtration; get rid of any leftover particles to achieve SDWA turbidity standards; Ways to filter include:
  - Granular media filtration after sedimentation; pretty standard
  - Direct filtration for clean raw waters w/average turbidity < 10 NTU
    - Coagulation goal for direct filtration: create a pin floc
  - Membrane filtration (ultrafiltration) for really clean raw waters
    - Why try to make lots of floc if the water is already pretty clear?
    - Great way to remove Giardia & Cryptosporidium cysts (if present)
  - Other variations of filtration
    - Manganese greensand media for iron and manganese removal
    - After a lime softening process
- Disinfection to kill any leftover pathogens

Conventional trt scheme for "turbid" water

- Treatment goals: remove settleable & suspended sediments and pathogens in raw water
- How?
  1. Start with a BIG pond to store diverted water; remove settleables
  2. Add chemicals to destabilize suspended colloidal solids so they stick together & settle: Use rapid mixing, coagulation, and flocculation to get something that will gravity settle
  3. Gravity settle the flocs; Target clarity is 2-4 NTU for settled water
  4. Filter out remaining solids to achieve ≤ 0.3 NTU for filtered water turbidity in 95% of all filter cell turbidity readings
  5. Disinfect the water to kill remaining pathogens

What we are covering now:

- ❑Who is in class & types of water systems we run
- ❑Review of key stuff from Part 2 Class
- ❑ Intensified water treatment processes; doing more treatment in less space and doing it faster
- ❑Managing water treatment residuals
- ❑ Optimizing performance of water trt. processes taught in this class
- ❑ Fun with word problems & water treatment math

What are intensified processes?

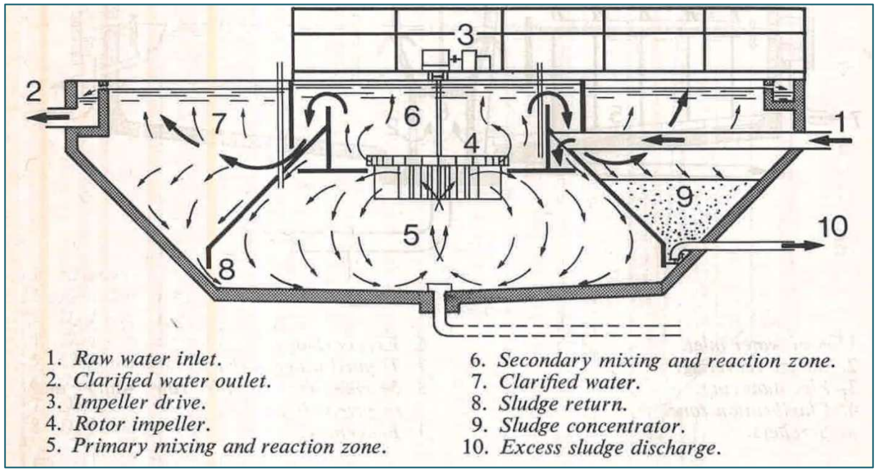
- ❑ They provide treatment faster and with smaller footprints than conventional systems
  - ❑ Often used to expand a facility with limited land space
  - ❑ They may also give a better overall result e.g., less chemical use or better quality finished water

- ❑ Examples of intensified treatment processes we will cover:
  - ❑ Solids Contact / Slurry Recirculation Clarifier
  - ❑ Buoyant Upflow Media Clarification
  - ❑ Dissolved Air Flotation
  - ❑ Sand Ballasted Flocculation
  - ❑ Membrane Filtration

Solids Contact / Slurry Recirculation Clarifier

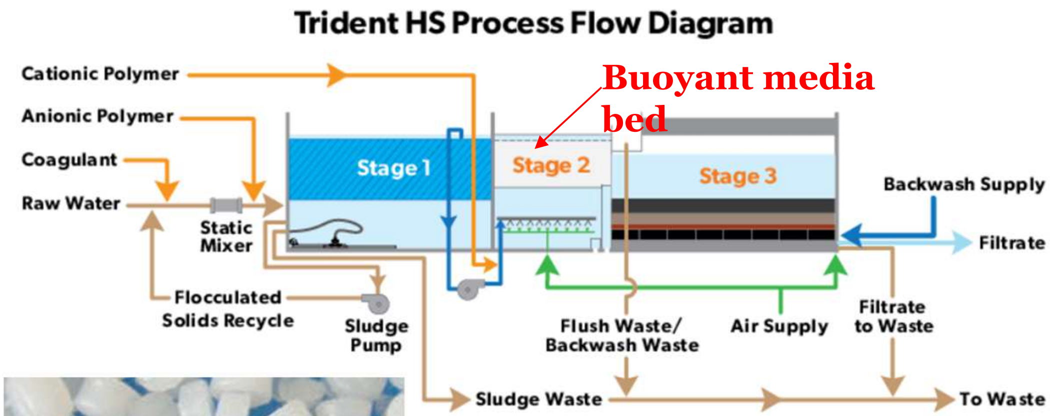
- ❑An "old school" intensified process developed in the 1950s
- ❑Efficiently combines rapid mixing, coagulation, flocculation, & settling in a single, *circular* tank
- ❑Recirculates settling sludge to the flocculation zone for more efficient use of coagulants
- ❑Promotes denser, more compact sludges, particularly in softening applications
- ❑Ideal for lime softening; also sediment-laden river water

Images courtesy of Veolia-Suez



Buoyant Upflow Media Clarification

- ❑An intensified process developed in the early1980s
- ❑Uses buoyant coarse plastic media to trap flocs ahead of granular media filter
- ❑Nominal rise rate: 10 gpm/ft^2
- ❑Screens trap media in the tank
- ❑ Uses air scour and water wash to clean plastic media
- ❑Sometimes combined with a tube settler equipped-clarifier
- ❑ Used at Bloomfield, NM WTP



Adsorption Clarifiers use buoyant media in an upflow system design.

Images courtesy of WesTech Engineering

Dissolved Air Flotation Clarification

Sometimes in surface water treatment, *YOU <u>CAN</u> BEAT GRAVITY!!*

- An intensified process borrowed from wastewater treatment
- Sometimes "gravity is overrated" when goal is to remove algae or low-density solids
- Nominal rise rate: 10-20 gpm/ft^2
- Uses fine dissolved air bubbles to float material to be removed; Smaller air bubbles are more efficient at floating the material
- Makes a compact pre-treatment solution for membrane filtration

Image courtesy of Veolia-Suez

Sand Ballasted Flocculation

"Making gravity work better"

- ❑First used in Rocky Mtn Region in mid-1990's in Colorado
- ❑Adds powder-like sand with specific gravity = 2.65 during flocculation to get denser, heavier flocs
- ❑Nominal rise rate: 35-50 gpm/ft^2
- ❑Uses cyclone separator to recover sand from the flocs and re-use in the process
- ❑Completes rapid mix, coagulation, flocculation, & settling in just 30 minutes!

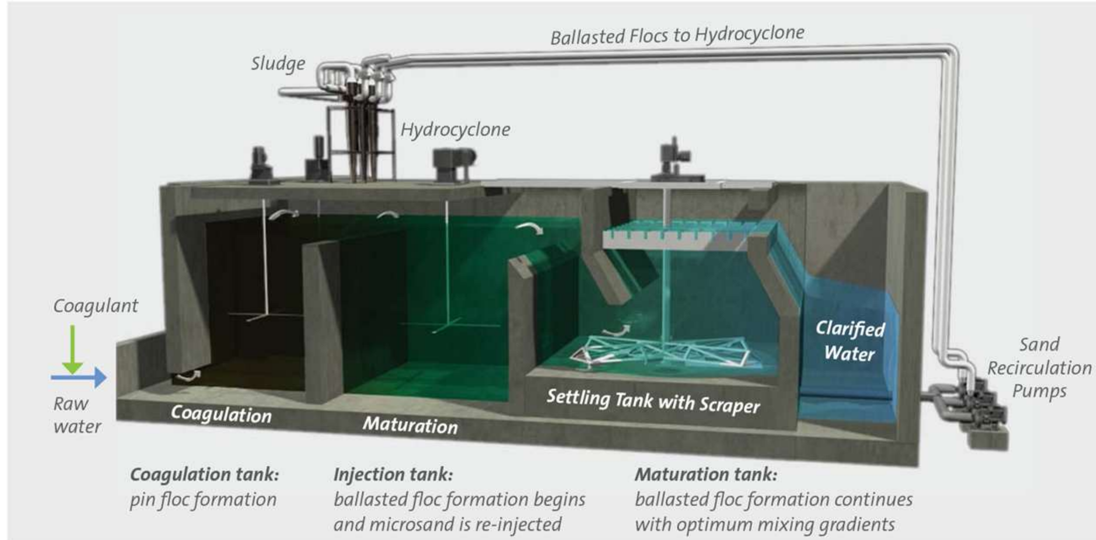
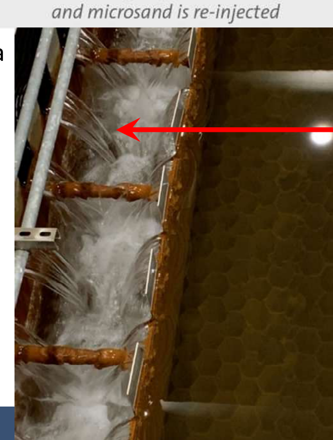


Image courtesy of Veolia



Turbidity = 1.25 NTU in effluent at SJCWTP

Membrane Filtration

- ❑First used in Ft. Lupton, CO in late1990's; 4.3 MGD plant
- ❑Great for clear cold waters with cysts or dissolved organics issues
- ❑Membrane flux rate: 30-35 gpm/ft^2
- ❑Combine w/varying types of pre-treat e.g., coag/floc or coag/floc /settling to convert dissolved stuff into filterable material ≥ 0.02 µm (Ultrafiltration)
- ❑Periodic air scour / water backwash & chemical cleaning of membrane modules to maintain design flux rate
- ❑Automated testing of membrane integrity; Whole system is automated!

Image courtesy of Pall Water

What are covering now:

- ❑Who is in class & types of water systems we run
- ❑Review of key stuff from Part 2 Class
- ❑ Intensified water treatment processes; doing more treatment in less space and doing it faster
- ❑Managing water treatment residuals
- ❑Optimizing performance of water trt. processes taught in this class
- ❑ Fun with word problems & water treatment math

Managing Water Treatment Residuals

- ❑Questions for a holistic approach to residuals management:
  - ❑Quantify the issue you want to manage:
    - ❑Backwash water management: high volumes of low solids content water that you may be able to re-use after some liquid/solids separation
      - ❑What is the volume generated per cleaning? # cleanings per day? Seasonal variability?
      - ❑Where and how will you re-introduce this "free water" back into the treatment process without upsetting finished water quality? Remember: The Filter Backwash Recycling Rule
    - ❑Clarifier sludge management: low volume sidestreams w/high solids content which may not be as useful to reclaim
      - ❑*Will recycling this water introduce trace contaminants not found in the raw water?*
  - ❑Once you've collected & processed the solids, what do they contain and how will they be disposed or possibly re-used?

Managing Water Treatment Residuals

- Questions for a holistic approach to residuals management
  - What regulations apply to the handling & disposal of the solids?
  - Does the clarifier sludge volume to be managed justify a permanent on-site facility for dewatering?
    - Will dewatering facility be operated intermittently or continuously?
  - Is there a nearby sanitary sewer with hydraulic capacity available?
    - How will your residual discharges impact the sewer and the downstream wastewater treatment system?
    - What will you have to pay for disposal in the sewer? Is the "price right"?

Managing Water Treatment Residuals

- Observations from my experience in water treatment and sludge management:
  - Provide enough flow equalizing storage if you plan to recycle all of plant's backwash flows
    - Don't want to hold up filter cleaning when needed for lack of a place to process backwash flows…is the tail wagging the dog?
  - Alum sludges are harder to thicken & dewater compared to ferric
    - Limited prospects for re-using alum sludges; Something to think about if sewer discharge isn't an option & you want to switch from using iron salt coagulants!

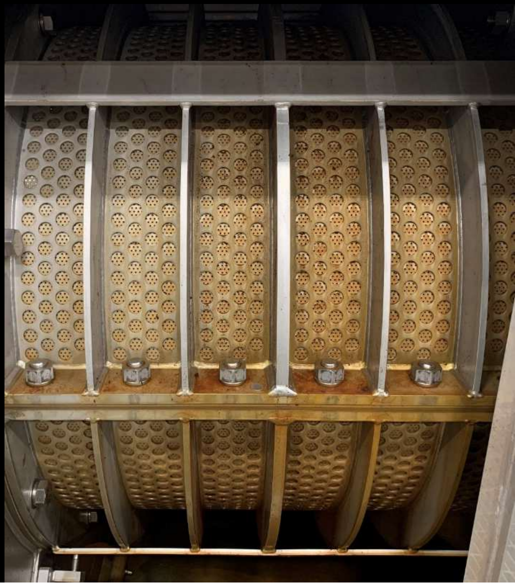
Managing Water Treatment Residuals

- ❑ Thoughts about dewatering water treatment plant sludges:
  - ❑ Drying beds w/concrete bottoms may work if enough space is available
    - ❑ Don't expect to decant much water or collect much filtrate in a drying bed
    - ❑ Limit the thickness of liquid sludge applied to 12 inches or less or else drying will take "forever"
  - ❑ Mechanical dewatering systems work best when fed continuously with "unlimited supplies of homogeneous materials"
    - ❑ How close can you come to providing this desired type of feedstock?
    - ❑ If continuous operation isn't a choice, How will sidestreams from start-up and shutdown conditions of the dewatering system impact the water treatment plant?
    - ❑ Centrifuges are NOT a good choice if routine operation will involve a lot of starting and stopping cycles;

Dewatering iron sludge at SJCWTP

- Things that make this system work well:
  - 500,000 gallons of **MIXED** equalizing storage
  - 40% active liquid emulsion polymer for flocculant; **NSF/ANSI-60 rated!!**
  - 2 mixed tanks in series for flocculating the sludge
  - Screw press technology; much simpler to operate compared to a belt press



What are covering now:

- ❑Who is in class & types of water systems we run
- ❑Review of key stuff from Part 2 Class
- ❑ Intensified water treatment processes; doing more treatment in less space and doing it faster
- ❑Managing water treatment residuals
- ❑Optimizing performance of water treatment processes taught in this class
- ❑ Fun with word problems & water treatment math

Optimizing arsenic removal using absorption media

- ❑Why do we care? Media replacement is expensive so get the most from what you have in your vessels!
- ❑ Blend with untreated water to achieve an arsenic level < 10 µg/L
  - ❑Need accurate flow metering on both treated flow and bypass flow
  - ❑Carefully track the volume treated and compare to manufacturer's projected Bed Volume & bed life
  - ❑Check for arsenic breakthrough once at 90% of mfr's. projected Bed Volume
- ❑ Adjust pH of water into treatment vessels to the range recommended by media supplier; it **WILL** help preserve media life!
  - ❑Adjusting pH using CO2 feed systems is *MUCH BETTER* than using liquid mineral acids like HCl

Optimizing floc.-sed. in conventional water treatment systems

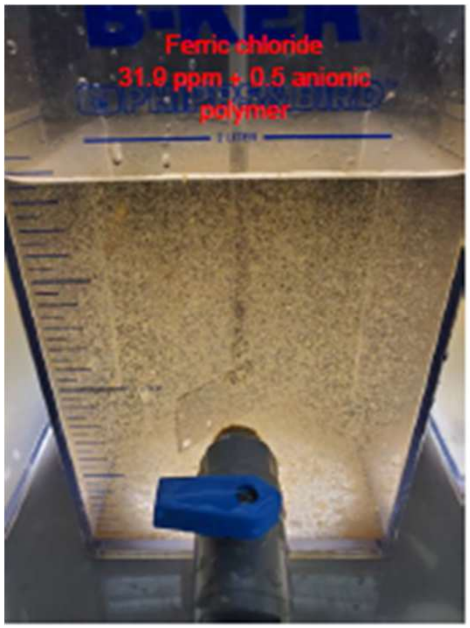
- ❑Why do we care? Save on chemical costs, produce less waste to manage, & improve downstream filter performance & run times!
- ❑ Variables to adjust to improve floc-sed performance include:
  - ❑Physical location where coagulant chemicals are added
  - ❑Flocculator speed adjustments
  - ❑Rate of withdrawal for settled sludge
  - ❑A little turbidity carryover from settling at 3 NTU might be OK if it lets the filter ripen faster and IF you can maintain it steady at 3 NTU
- ❑ Any seasonal changes in water temp. & viscosity? These will impact coagulant performance; Optimal feed rates & locations for summer vs. those for winter; These may change!

Optimizing floc.-sed. in conventional water treatment systems

- Optimizing flocculation is all about creating the right surface charge conditions in the floc
  - Assess by measuring Zeta potential which measures surface charge of floc particles; streaming potential can also be useful
  - Floc particles w/negative charge will get removed on the filter *BUT* they won't get "glued" to media grains; easier to flush out during filter backwash!
- Assess coagulant performance using jar tests
- Sometimes, it's just time to change the coagulant you use!

Optimizing floc.-sed. in conventional water treatment systems

- Pictures from circa 2022 coagulant jar test study at SJCWTP



- The anionic polymer together w/ferric chloride creates a floc that is less “sticky” than with cationic polymer; look at jar walls!

QUIZ: Turbidity in water...

- A. Is an accurate measure of a water's cloudiness
- B. On average, should measure 1-3 NTU in the water entering filters
- C. Is exactly equivalent to TSS; 1 NTU = 1 mg/L of TSS
- D. Can cause filtrate NTU to spike if the filter loading rate changes suddenly
- E. All of the above
- F. A, B, and D

Hints that granular media filter performance is "sub-par"

- Shorter filter run times between cleanings?
- Poorer results for filtrate turbidity?
- Too long to ripen a filter?
- Get turbidity spikes from remaining filters when washing a filter?
- Cratering of media, uneven media surface, or cracking of surface?
- Air release from filter bed during backwash?
- Filter media observed in the wash troughs?

Hints for improving filter performance

- ❑Track Unit Filter Run Volume; Filtrate gallons/SF of filter area
  - ❑ UFRV should be > 5,000; **If not, determine why not!**
- ❑Colder water temps allow for slower backwash rates
  - ❑Have you adjusted your backwash flow rates if BW water is colder?
- ❑Performance of clarifiers; too much polymer in the floc creates stickier flocs that are hard to remove during backwash
- ❑Check Zeta potential of water onto filter; Do the particles to be filtered out have a negative charge? (The filter media usually does)

Hints for improving filter performance

- "Downshift" plant production rate when cleaning a filter; Greater flow through remaining filters can cause turbidity spikes if plant production flow is left constant
- Are backwash cycles too long? Check BW turbidity at even time intervals thru the whole sequence; Once BW washwater NTU measures 15-30 NTU, consider ending backwash
  - A clean filter is good. A "squeaky clean" filter? Not so much!
- Stepwise approach to evaluating filters: AWWA DVD: Filter Surveillance Techniques For Water Utilities
- What type of water do you use to re-fill the filter box before returning it to service?

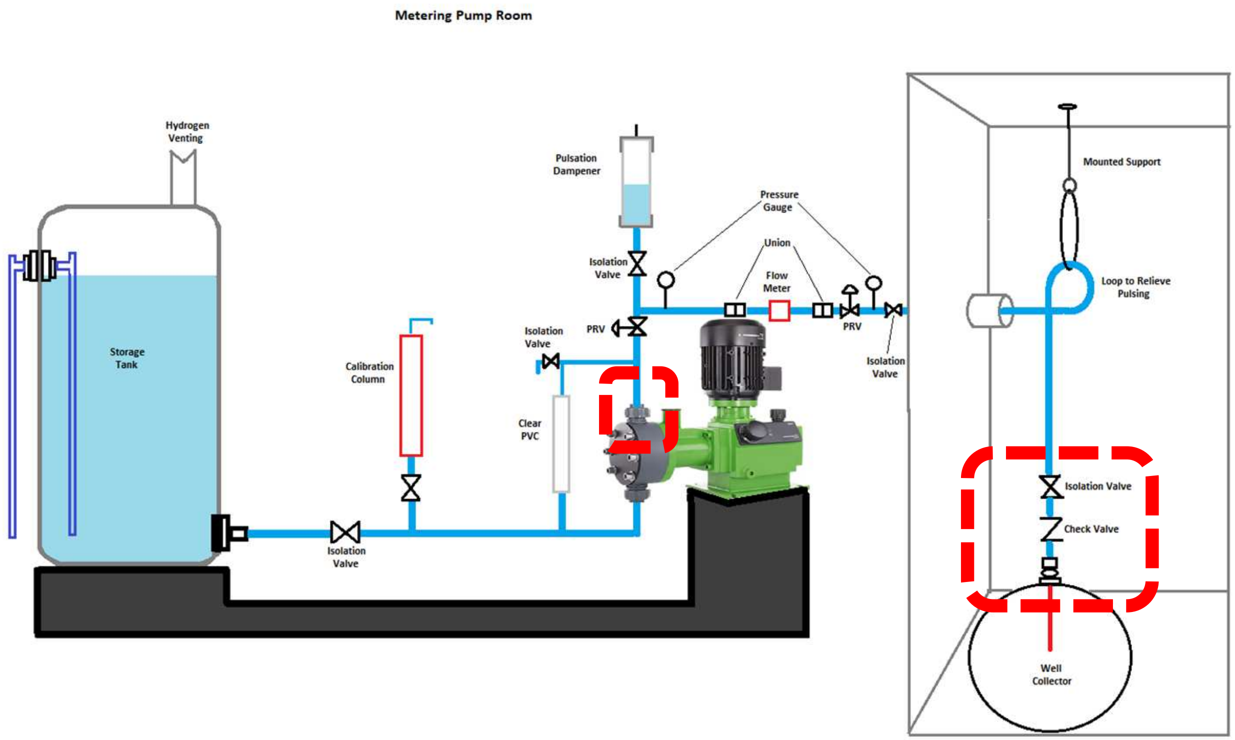
Trouble improving filter performance?

- ❑ Consider joining AWWA Partnership for Safe Water-Treatment
- ❑ A way to achieve compliance by optimizing operations *(more $$ for capital improvements may just be part of the answer)*
- ❑ PSW-Treatment main goal: Are ≥ 95% of all filtered water turbidity readings < 0.10 NTU? *If not, WHY NOT??*
- ❑ PSW-Treatment has 4 key steps:
  1. Sign up & commit; *Only $50/year for small systems!*
  2. Collect & submit filter turbidity data on PSW-Treatment website
  3. Complete detailed self-assessment & submit to AWWA Partnership program folks; *146 "easy" questions*
  4. Commit to making incremental improvements each year on those items you select to make your treatment plant run better

POLL: What chemical does your system use for disinfection?

- A. Chlorine gas
- B. Liquid sodium hypochlorite (NaOCl or bleach)
- C. On-site generated hypochlorite (HOCl)
- D. High Test Hypochlorite (HTH) tablets disinfection
- E. Chloramines

Potential issues with liquid sodium hypochlorite feed



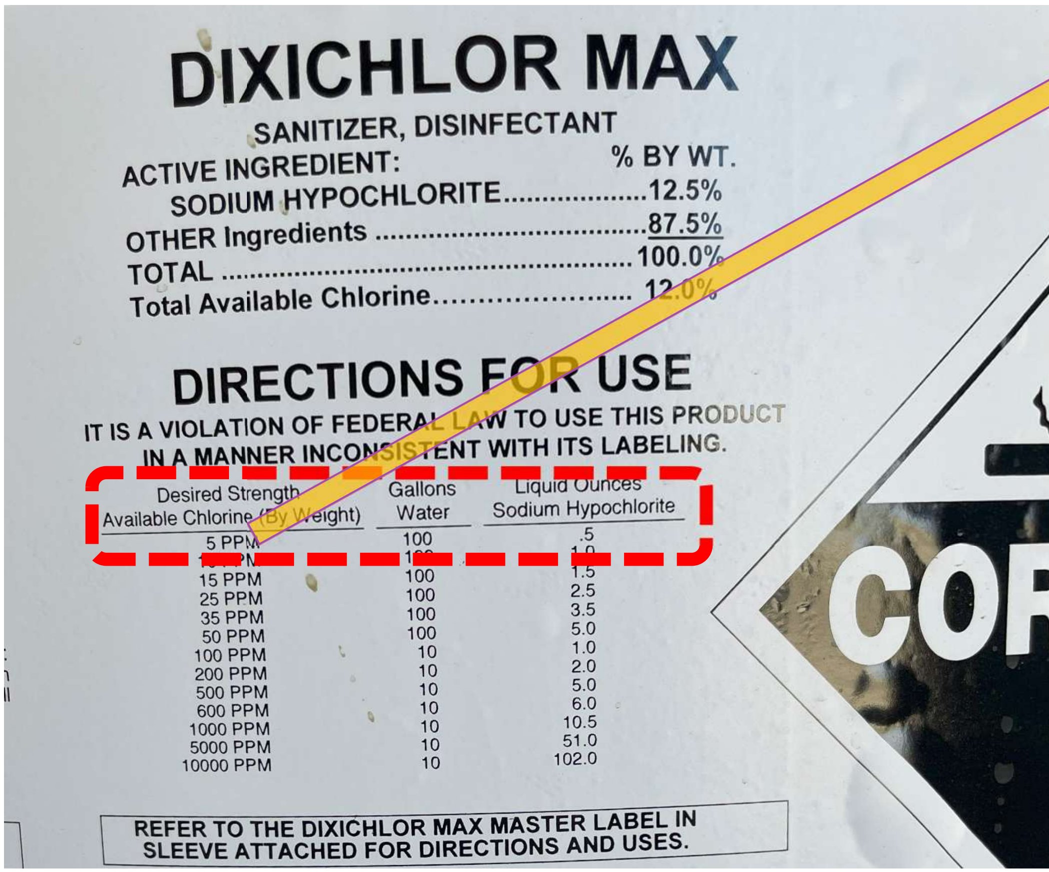
- **A.** Off-gassing of NaOCl solution can be a problem; Pumps can vapor lock w/typical 12.5% solution

Possible solution: peristaltic feed pump

- **B.** 12.5% solution degrades w/time; worse if temp > 70ºF

- **C.** Plugged injector quills

Recipe for getting the desired chlorine dose at a 1 MGD treatment plant starting with 12.5% liquid NaOCl



- Wanted: 2 PPM dose of available Cl
- 0.5 * (2/5) = 0.2 liquid ounces in 100 gallons or 2,000 liquid ounces in 1,000,000 gallons
- 2 PPM dose in 1 MG requires (2,000/128) = 15.6 gallons of DIXIECHLOR MAX product (Remember, there are 128 fluid ounces in a gallon)
- 15.6 gals/day of DIXIECHLOR covers 2 PPM dose for a 1 MGD finished water flow
  - (15.6 gallons/day) x 128/1440 = 1.39 oz/minute
  - 1.39 oz/minute x (29.57 ml/oz) = 41 ml/minute

Lots of metering pumps for sale to feed 0 - 100 ml/min! Running it at 41% of full speed makes a 100 ml/minute capacity pump a good choice!

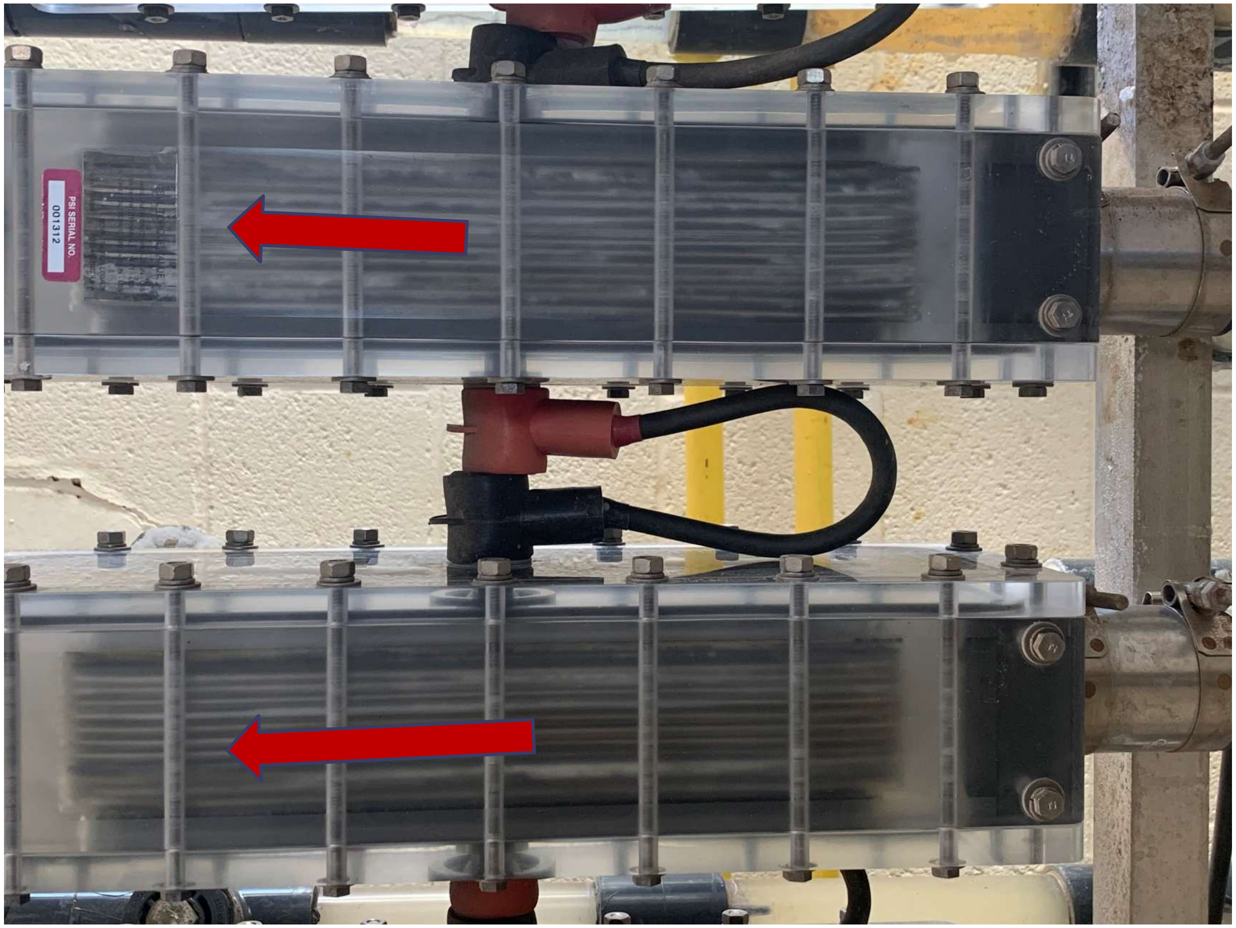
Keeping on-site HOCl generators reliable

- Softened water *is a must* for brine make-up supply and dilution water flow into generator; Softened means 0 mg/L = 0 grains/gal of hardness

- Softener sizing needs to be matched to the flow rate of the generator brine feed pump; critical for correct micro nozzle sizing in the softener vessel control head

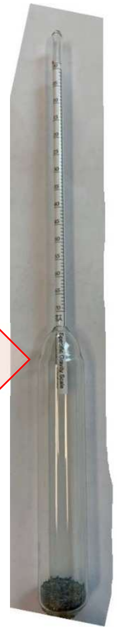
- Even w/soft water & good quality salt, on-site generator cells will need periodic muriatic acid cleaning

On-site HOCl generator cells up close:



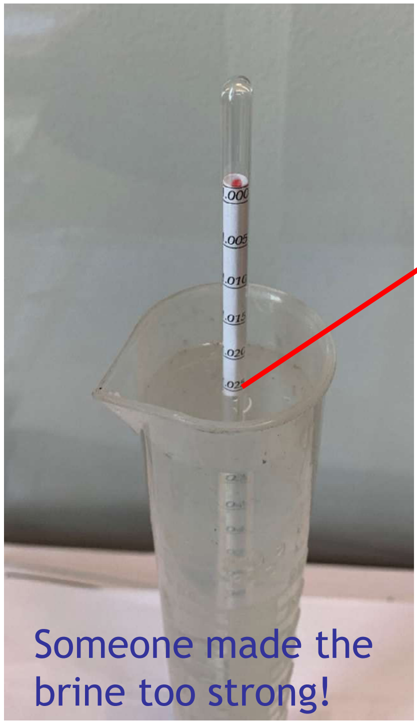
KPI's for On-site HOCl generators

- Make-up water hardness (Is the softener working right?)
- Run hours between chemical cleanings
- Amperage draw of generator
- Amperage draw & voltage per generator cell
- Brine strength using a hydrometer
- HOCl solution strength (check by titration)
- Temperatures of generator cells & power supply cables

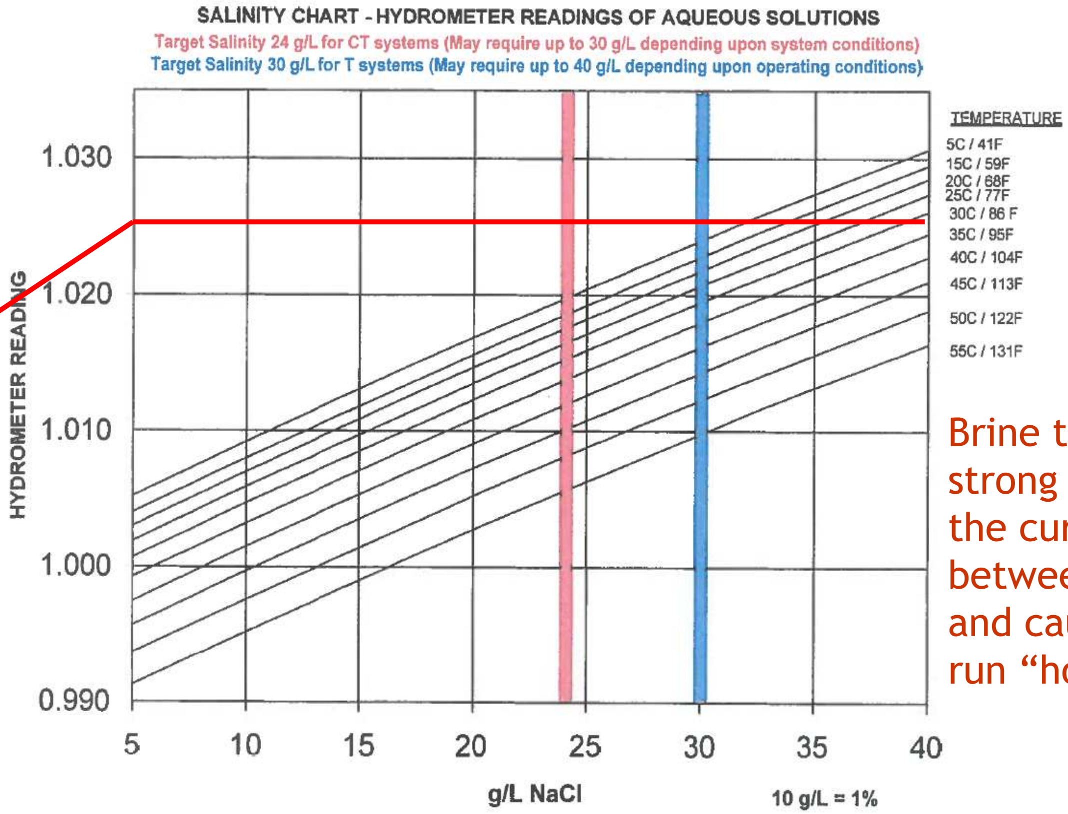


KPI's for on-site HOCl systems

Brine strength



Someone made the brine too strong!



Brine that is too strong will increase the current flow between cell plates and cause the cell to run "hot"

What are covering now:

- ❑Who is in class & types of water systems we run
- ❑Review of key stuff from Part 2 Class
- ❑ Intensified water treatment processes; doing more treatment in less space and doing it faster
- ❑Managing water treatment residuals
- ❑Optimizing performance of water trt. processes taught in this class
- ❑ Fun with word problems & water treatment math

QUIZ: **A well field produces 465 gpm for 90 hours each week & uses 12.5% liquid bleach (avail. NaOCl). If the dose = 1 mg/L Cl_2 how many 50-gallon barrels of 12.5% bleach are needed every 12 weeks? Assume 12.5% NaOCl contains 1.2 lbs of Cl_2 per gallon**

A. Three (3) barrels

B. Four (4) barrels

C. Six (6) barrels

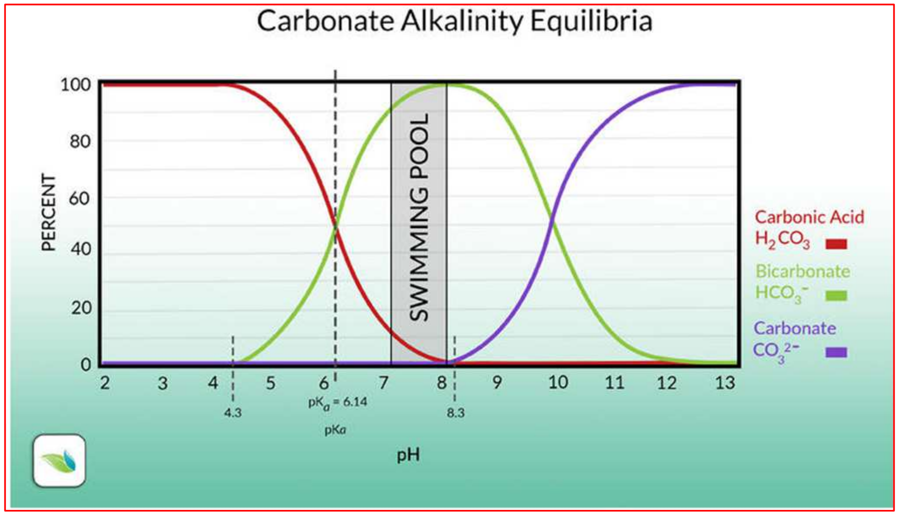
Solution Hints:

1. Calculate the total volume of water treated in 12 weeks = Q x T = V
2. Calculate the lbs of Cl_2 needed to achieve the 1 mg/L of Cl_2 dose = Vol treated in Million Gallons x mg/L dose x 8.34 = total lbs Cl_2 = ???
3. Calculate the equivalent gals of 12.5% NaOCl bleach using the conversion factor provided of 1.2 lbs avail Cl_2 per gallon
4. Knowing the total # of gallons of 12.5% bleach required, convert to equivalent # of 50-gallon drums

QUIZ: **The Sunnyside WTP in Florida uses lime softening. Of late, filter run times after softening have been much shorter. The pH of softener effluent onto the filters has been trending upwards to 9.6. The most likely explanation for shorter filter run times is…**

- A. Inadequate filter cleaning procedures
- B. Overdosing of polymer feed that's used together with lime addition
- C. Feed of CO_2 into the recarbonation tank that follows softening is too low
- D. Feed of CO_2 into the recarbonation tank that follows softening is too high

Hint: The plant feeds CO_2 after softening to form H_2CO_3 or carbonic acid and **STOP** precipitation caused by softening



Graph courtesy of Orenda Technologies

QUIZ: **Each vessel in a 3-vessel arsenic removal system has 314 CF of media. It runs 24/7/365 at 5 MGD with 50% the flow being bypassed for blending. If the media is rated for 150,000 bed volumes, how many days before a media change is required?**

- **A. 471 days**
- **B. 211 days**
- **C. 423 days**
- **D. 141 days**

Solution Hints:

1. Draw a picture of this system and label it with the correct flow rates including the portion of flow that is ***NOT*** going through the vessels!!
2. At 314 CF of media per vessel, the total available media volume is…
3. Convert total media volume in CF to media volume in gallons
4. With 150,000 bed volume rating, the 3-vessel system can treat ??? gallons before change out
5. V / Q; Max volume that can be treated ÷ flow rate = days of service

QUIZ: **Based on SCADA data, the Purewater WTP's 8 filters each w/10’x20’ of surface area produced 12.8 MG of filtrate in January 2024 just before a media change-out project. What was the Unit Filter Run Volume (UFRV) for this set of 8 filters?**

- **A. 8000 gal/SF**
- **B. 1000 gallons/SF**
- **C. 4000 gallons/SF**

Solution Hints:

1. Draw a picture of this system and label it with the data given!
2. The total available filter area for the 8 filters is ??? SF
3. The total volume of filtrate produced was ???? gallons
4. Therefore, the UNIT FILTER RUN VOLUME in gallons/SF was ???

FINAL QUIZ: The filter media vendor for the Purewater WTP media change-out project claimed UFRV would increase by 30%. If the measured UFRV after media change was 10,000 gal/SF, calculate the corresponding filtrate volume produced. Was the vendor's claim realized?

- A. 16.64 MG and YES the vendor's claim was valid
- B. 16 MG and NO, the vendor's claim wasn't valid
- C. 20.32 MG and YES the vendor's claim was valid
- D. 8 MG & NO the vendor's claim wasn't valid

Solution Hints:

1. Draw a picture of this system and tag it with the data given!
2. The improved UFRV after media change out was 10,000 gal/SF
3. With the battery of eight 10'x20' filters, the total volume of filtrate produced by these 8 filters after media change out, V = UFRV x Total Area = ???
4. Compared to the old filtrate volume, the new filtrate volume is ???? % greater / smaller than before
5. Therefore, the vendor's claim that there would be a 30% improvement was…

THANK YOU AND WISHING YOU SUCCESS IN YOUR UTILITY OPERATIONS CAREER!

Charlie Leder, PE
Hazen and Sawyer
505-236-3889; cleder@hazenandsawyer.com
NM Water Systems License, Level 4, #12411