Introduction to Surface Water Treatment SDWA Regulations & Basic Chemistry

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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 8:55 AM: Surface Water Unit Treatment Processes and Treatment Systems
- Part 3 at 10:20 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!!**

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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: How many employees does your system have?

- A. Less than 2
- B. Between 2 and 4 employees
- C. Between 5 and 9 employees
- D. Between 10 and 20 employees
- E. More than 20
- F. Don’t know

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)

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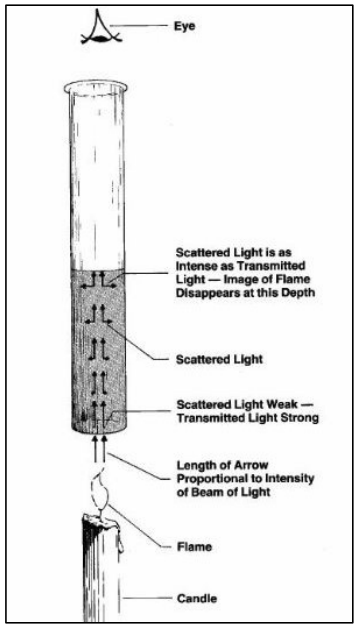
What's in the water that customers don't want?

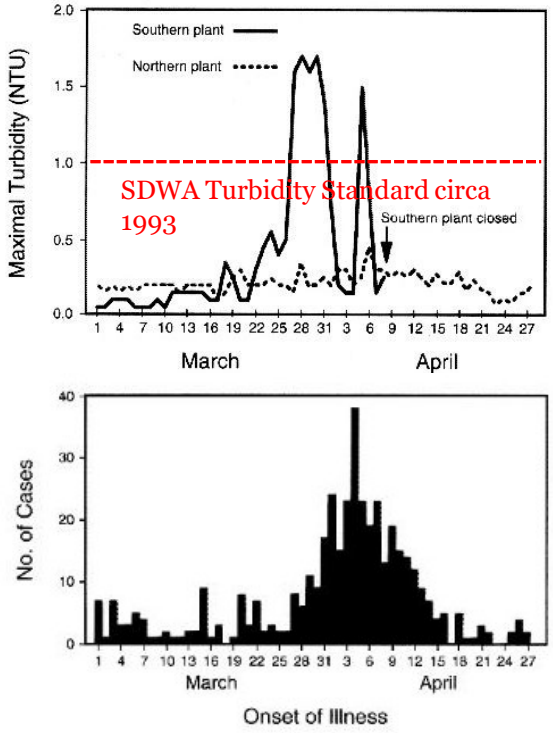
- Why do we care? "Knowing the enemy" means knowing how to attack
- Typical Surface Water Contaminants for "unpolluted sources":
  - Turbidity
  - Pathogens; Can be present even in clear cold water
  - Inorganic chemicals
    - Iron & manganese
  - Organic matter measured as Total Organic Carbon or UV254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

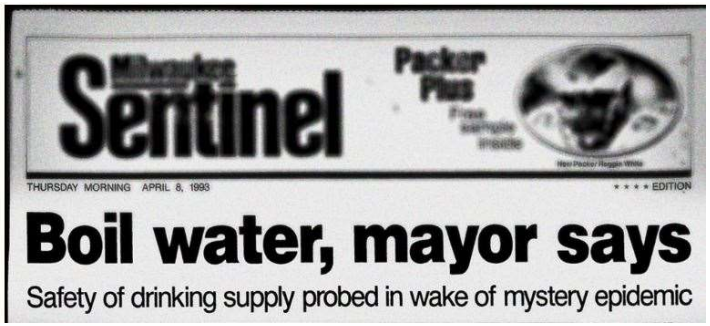
Why is removing turbidity so important?

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



Why is removing turbidity so important?





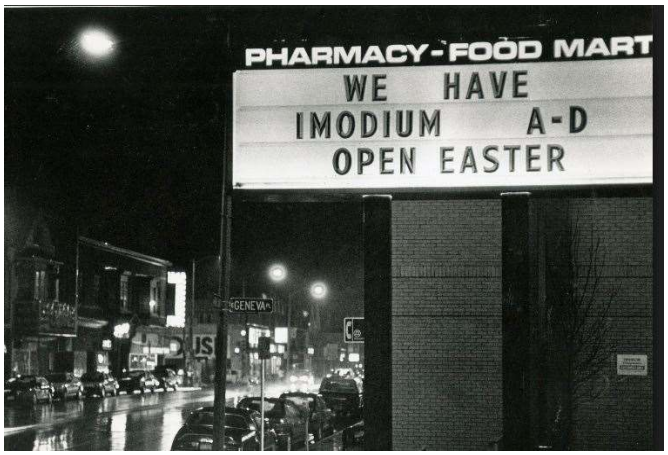


Photo images courtesy of Milwaukee Sentinel archives

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**

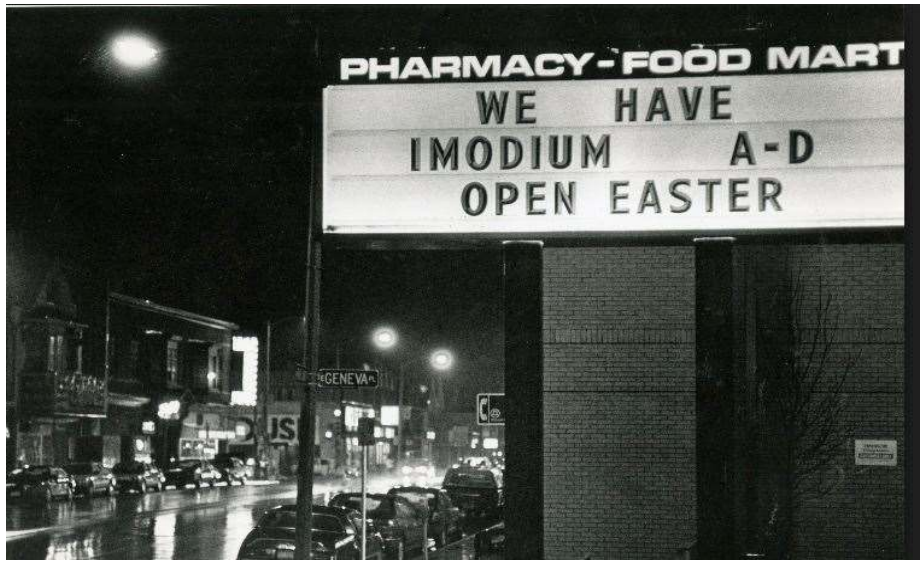


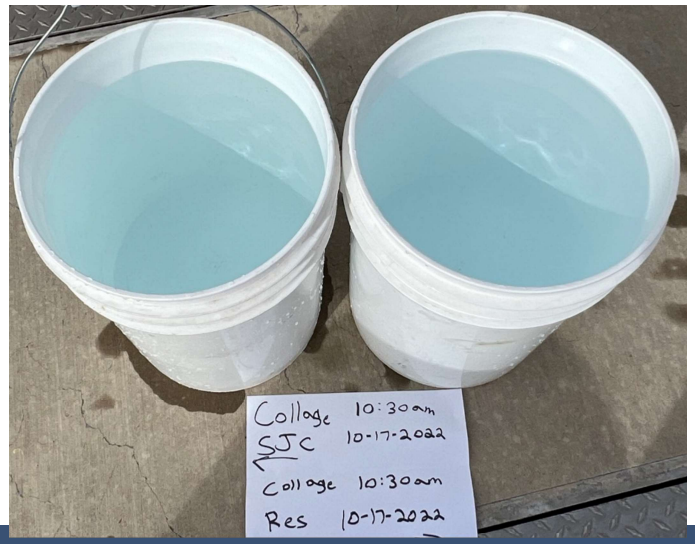
Photo image courtesy of Milwaukee Sentinel archives

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 WILL 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 with disinfectants to form Disinfectant By-Products
  - 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?)
- For stream or river diversions
  - Flashy turbidity conditions especially following thunderstorms
  - Burn scar runoff? Any folks here from Las Vegas or Village of Ruidoso?

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Da' rules for Surface Water Trt:

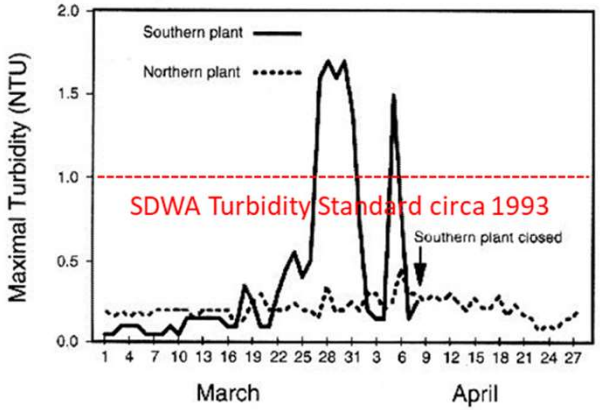
- Start w/SDWA MCLs for 125 primary contaminants
  - "Our raw water supply is pretty good" (except during disasters)
- Main Rules:
  - Surface Water Treatment Rule
  - "LT2ESWTR"
  - Revised Total Coliform Rule (RTCR); really about water quality in the distribution system & disinfection treatment; *Got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

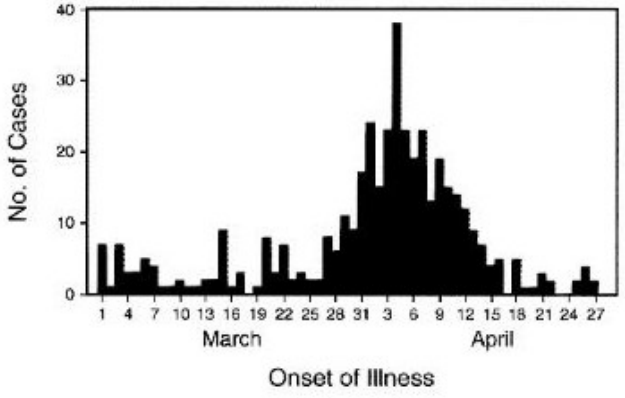
Surface Water Treatment rule(s):

- 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 c*ryptosporidium 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 turbidity 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

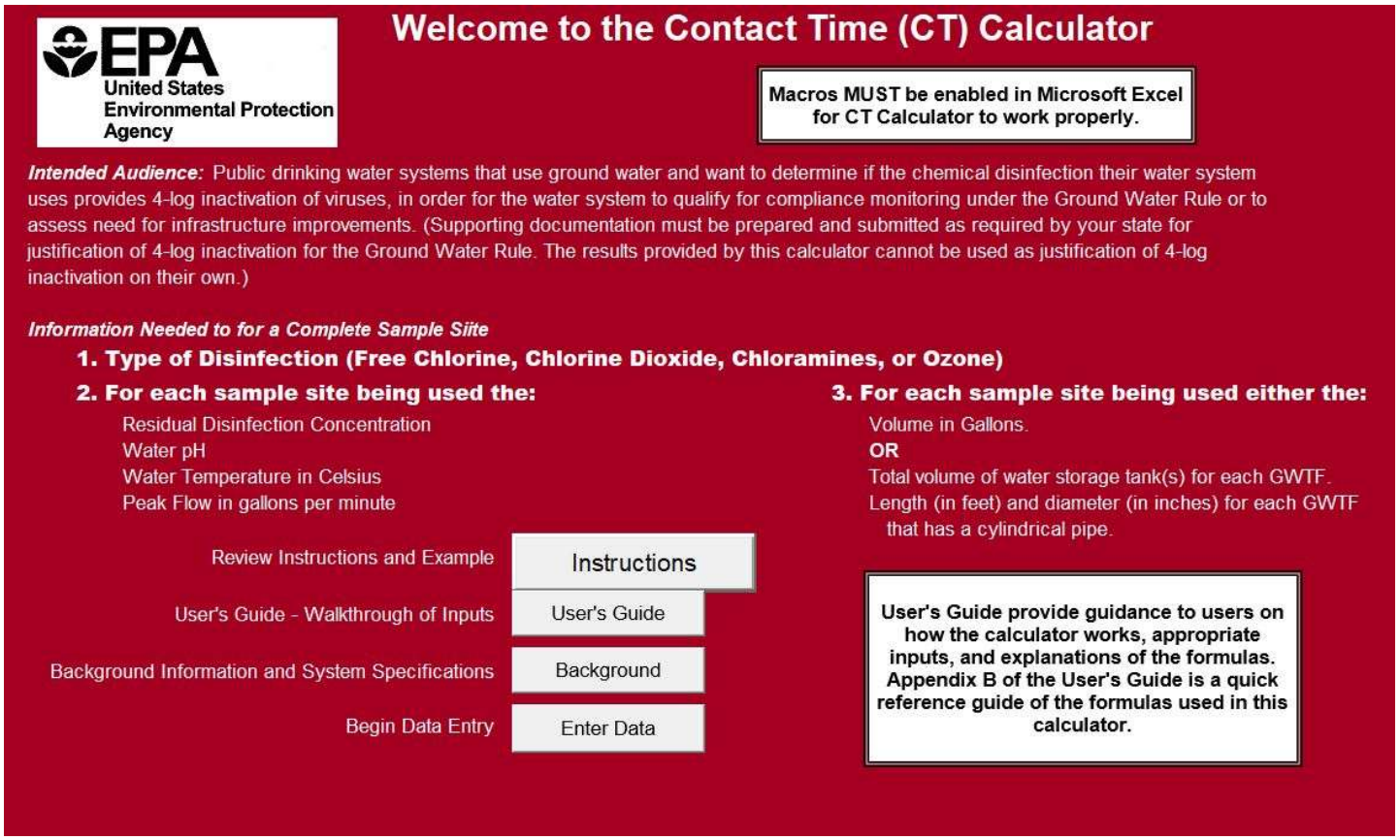
A. TRUE

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 data in SCADA and a spreadsheet for these calcs?*)

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 in11 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 now being considered by EPA
  - 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?

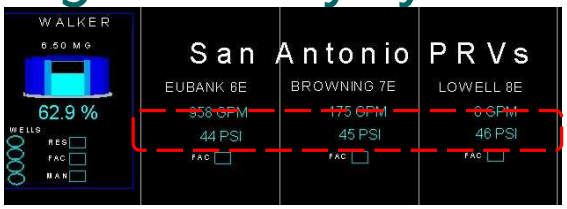
Trouble Consistently Meeting Da' Rules?

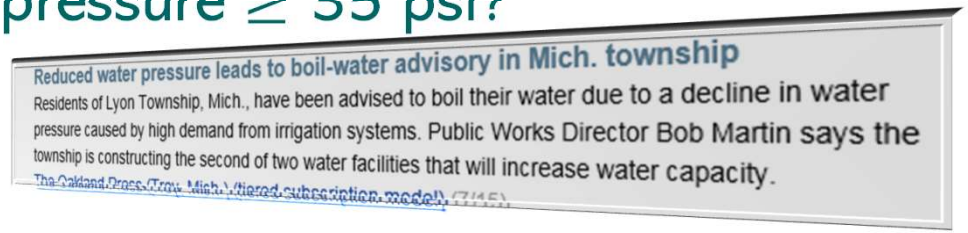
- Maybe join AWWA Partnership for Safe Water (PSW)-Treatment and/or PSW-Distribution
- A way to achieve compliance by optimizing your operations *(just more $$ for capital improvements may not be the best answer)*
- **MAIN GOAL** for PSW-Treatment : Get ≥ 95% of all your filtered water turbidity readings < 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*

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"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 $[OH^-]$

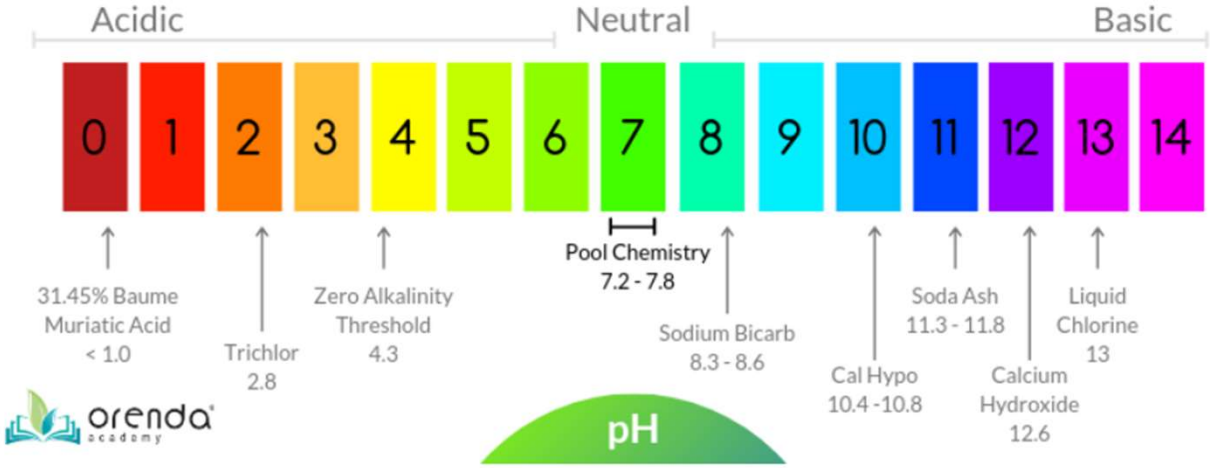


Figure courtesy of Orenda Technologies

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

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

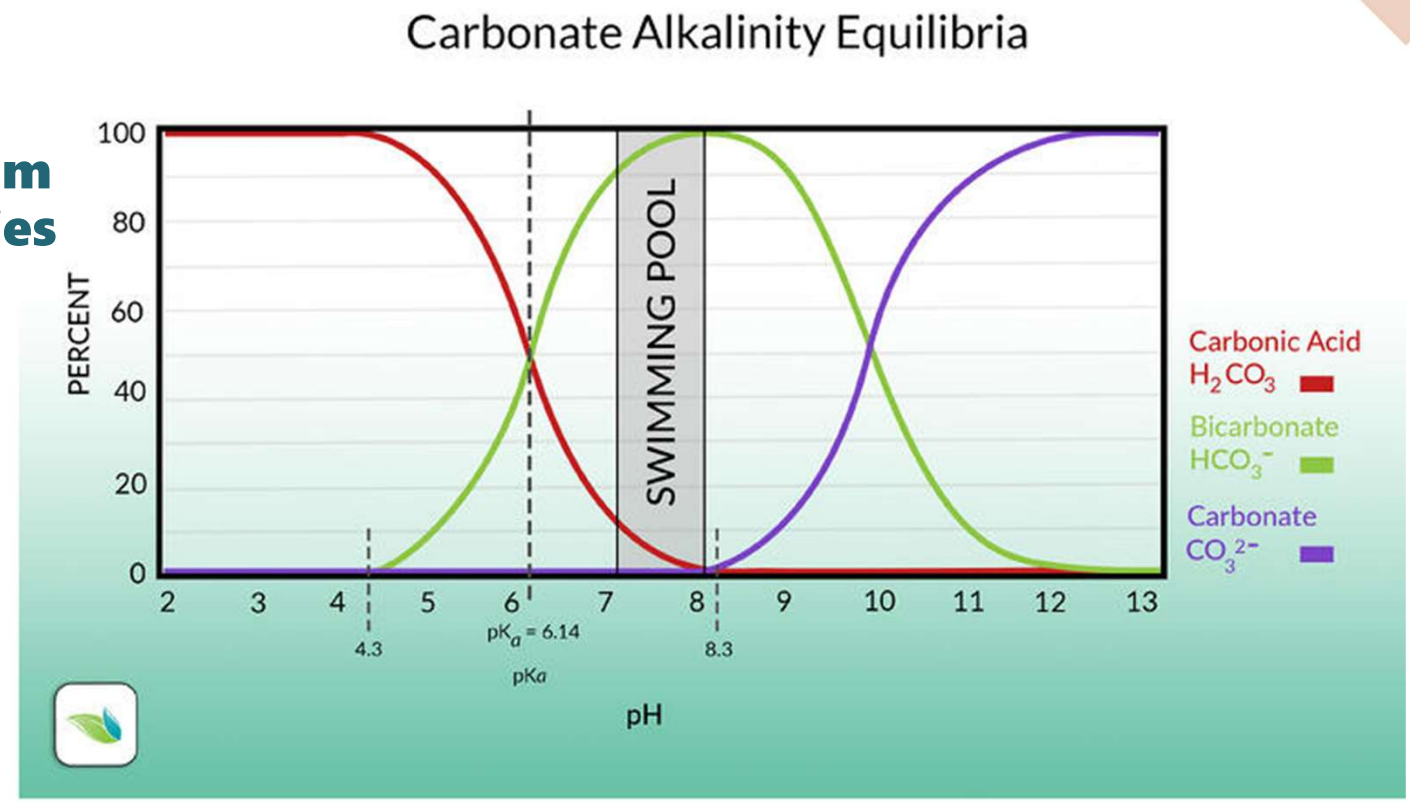
bicarbonate ion carbonate ion hydride ion

- 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

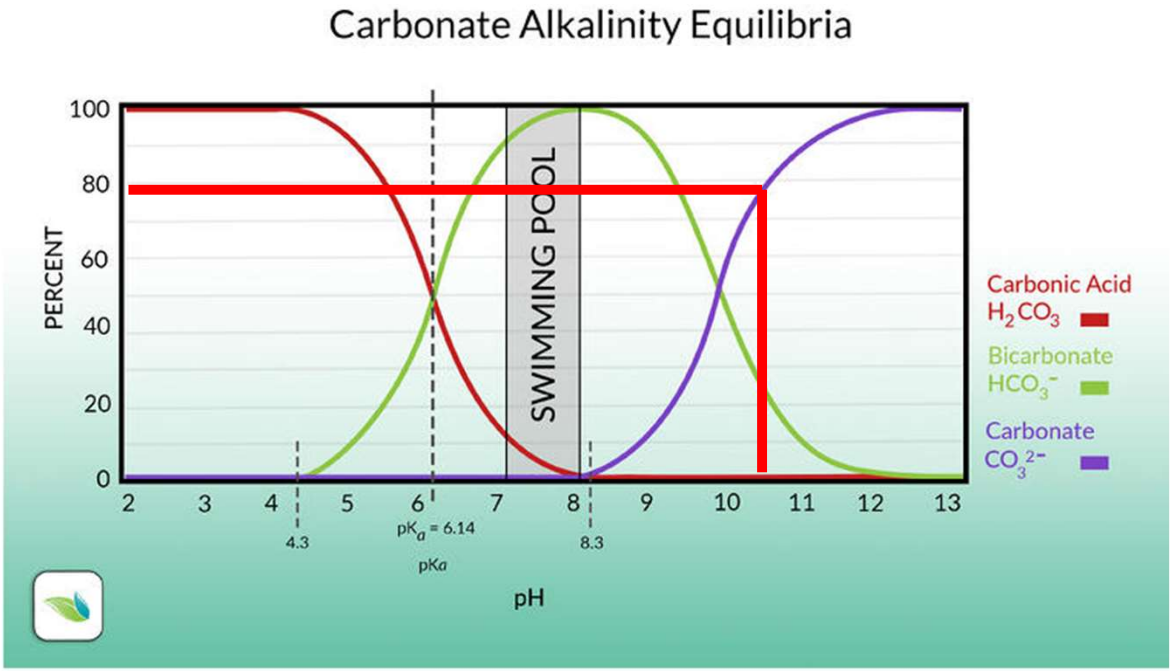
- **Useful chart for alkalinity equilibrium *or* which ionic species predominates in which pH range…**



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*:**

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

{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:

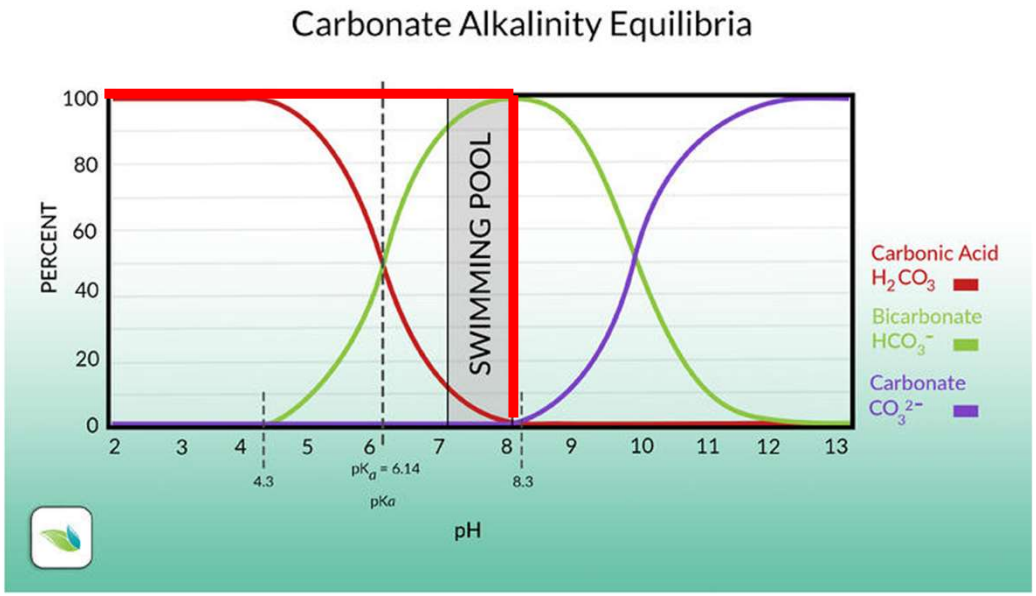
Ion name	Formula	Weight; mg/mole	Weight; milli-equivalent/mole	Conversion factor for $CaCO_3$ equivalent
Bicarbonate ion	HCO_3^{-1}	61	61	1.64
Carbonate ion	CO_3^{-2}	60	30	1.66
Carbonic acid	H_2CO_3	62	--	1.61
Hydroxide ion	OH^{-1}	17	17	5.88
Hydrogen ion	H^{+1}	1	1	100
Calcium ion	Ca^{+2}	40	20	2.5
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**



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

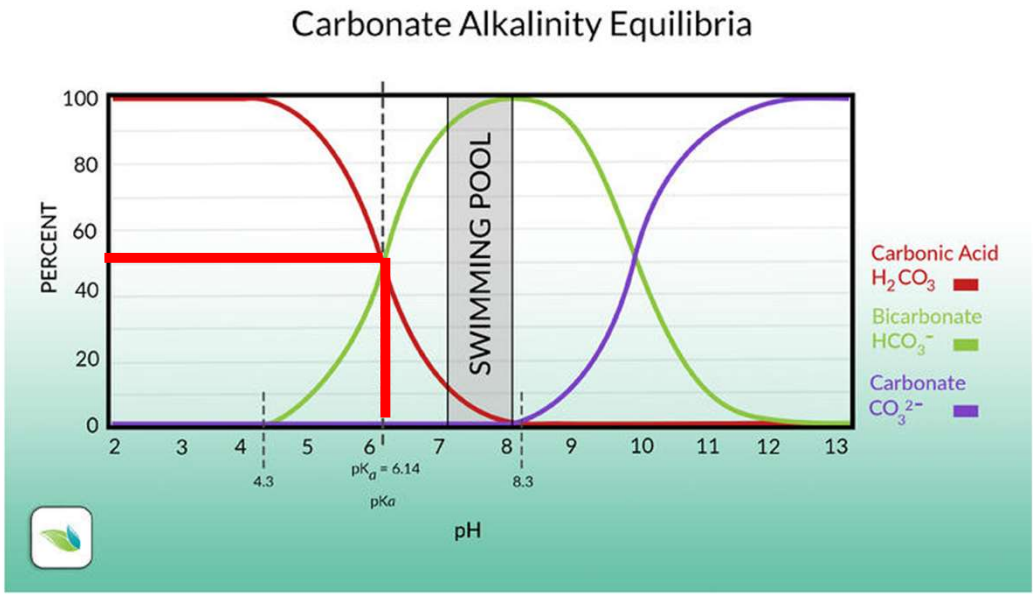
Graph courtesy of Orenda Technologies

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

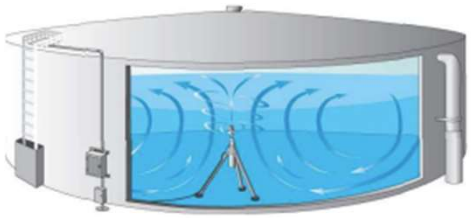
- Coagulants
  - Ferric chloride
  - Aluminum sulfate (filter alum)
  - Making a choice or change? Consider how you will manage the residuals from treatment; alum sludge management can be a pain
- pH adjusters
  - Take pH UP: Calcium hydroxide $Ca(OH)_2$ & Caustic soda NaOH; Stuff worth knowing
  - Take 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!

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