FAQs For Surface and Satellite Water Supplies that Chloraminate

Useful references materials

IRWA Homepage: http://www.ilrwa.org/
For VA/ERP and NAP: http://www.ilrwa.org/Downloads.htm
For Building flushing (reopening) directions (1st box on page): http://www.ilrwa.org/index.htm
For Illinois EPA Drinking Water Watch: http://water.epa.state.il.us/dww/
For Illinois EPA Sample Collector Handbook NAP Chapter:
https://www2.illinois.gov/epa/topics/compliance-enforcement/drinking-water/Documents/NAP-Handbook-final.pdf
For Subtitle F: Public Water Supplies, Chapter I Pollution Control Board:
https://pcb.illinois.gov/SLR/IPCBandIEPAEnvironmentalRegulationsTitle35
2018, Julie Sievers, Iowa DNR Presentation:
http://www.iowaruralwater.org/presentations/2018/IRWA-AmmoniaChlorine2018.pdf

Chlorination practices

You must either establish a **free chlorine** residual **OR** form **chloramines** in distributed water.

- With this said, in Illinois, pathogen inactivation through the use of free chlorine contact is routinely practiced in vulnerable (surface and groundwater under the influence of surface water source) systems.

Most Plants – **should** breakpoint to overcome chlorine demand and establish regulatory required contact time.

- Keep in mind source water quality will vary (e.g., time of year, weather conditions, etc.). Therefore, chlorine levels **MUST** be adjusted based upon testing.
- Competition exists for chlorine and you must overcome these reactions.
    - Generally, chlorine reactions follow this sequence:
        - Iron, Manganese, Hydrogen Sulfide, etc.
            - Iron will consume 0.64 times its concentration (mg/l) in Cl_2.
            - Manganese will consume 1.3 times its concentration (mg/l) in Cl_2.
            - Hydrogen Sulfide will consume 2.2 times its concentration (mg/l) in Cl_2.
        - Free Ammonia.
            - Removal of ammonia can be accomplished through biological treatment and cation exchange following removal of hardness (e.g., Reverse Osmosis followed by a cation exchange resign cartridge).
        - Monochloramine and Dichloramine.

Establish a “Free” chlorine residual.

- Theoretical: It takes 7.6 mg/L of chlorine to burn out 1.0 mg/l of ammonia and establish a free chlorine residual.
    - Remember you must overcome other reactions with things like Iron, Manganese, and Hydrogen Sulfide.
- Must maintain a minimum of 0.5 mg/l free chlorine residual in all areas of the distribution system.

Maximum NSF chlorine feed = 30 mg/l (as Cl_2) for gas and 10 mg/l (as Cl_2) for Sodium Hypochlorite (80 mg/l for 12.5% solution as product).

- This feed rate includes the sum of all points of application (pre, in process and post) and is based upon contaminants present when the gas or solution is made by the manufacturer.
- In round numbers, if using sodium hypochlorite anything over 1.3 mg/l of free ammonia in the source water and chloramine formation is needed. Likewise, if using gas Cl_2 anything over 3.9 mg/l of free ammonia in the source water and chloramine formation is needed.
    - Experience in IL is that, competition for Cl_2, maximum free ammonia of 1.0 and 3.0 mg/l for hypo and gas respectively.

Too many TTHM or HAA precursors to maintain a free residual in distributed water

Must form chloramines (specifically, monochloramine) following pathogen inactivation.

- As a starting point use the correct chlorine dosage to react with the ammonia present in the water, establish a chlorine to ammonia-N ratio of 5.06 to 1.
    - Remember, there is competition for chlorine and presence of iron and H_2S (etc.) is a factor.
- Must maintain 1.0 mg/l of total chlorine in all areas of the distribution system.
    - IMPORTANT NOTE: IF YOU ARE CHLORAMINATING YOU **WILL NOT** HAVE ‘FREE CHLORINE” PRESENT.
        - Discontinue testing and reporting!

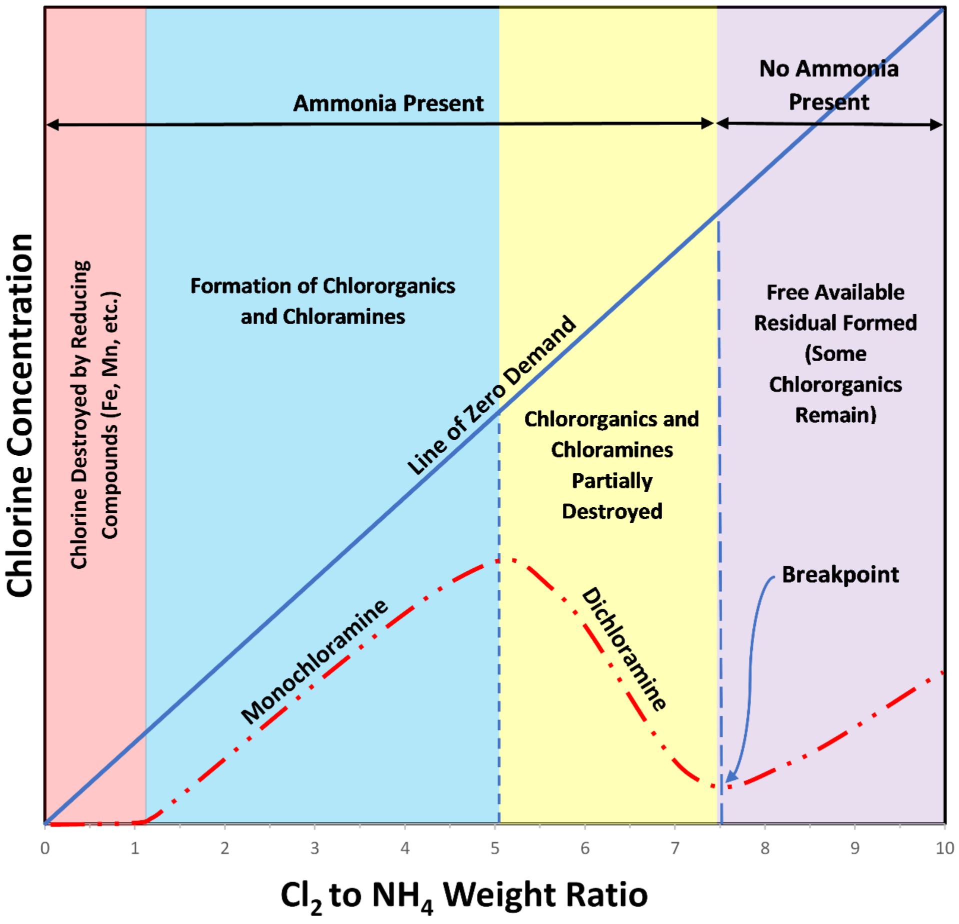
Optimize chemical addition through reviewing water quality parameters and testing.

- Remember NSF maximums still apply.
    - This feed rate includes the sum of all points of application (pre, in process and post) and is based upon contaminants present when the gas or solution is made by the manufacturer.
    - In round numbers, if using sodium hypochlorite anything over 2.0 mg/l of free ammonia in the source water and ammonia will not be bound up in the formation of monochloramine. Likewise, if using gas Cl_2 anything over 5.9 mg/l of free ammonia will not be bound up in the formation of monochloramine.
        - IF AMMONIA IS TOO HIGH, YOU PHYSICALLY **CANNOT FEED ENOUGH CHLORINE TO BREAKPOINT – EXCESS FREE AMMONIA WILL GET INTO THE DISTRIBUTION SYSTEM**

Optimize chemical addition through reviewing water quality parameters and testing.

- Gradually increase chemical dosage without exceeding NSF feed rates.
- Do not get on the wrong side of the curve by overfeeding Cl_2 **residual will go down.**

Breakpoint Chlorination Schematic



Refresher on the breakpoint curve

Until you reach breakpoint (7.6 to 1), **adding chlorine to water containing monochloramines with no free ammonia, will form dichloramine** (moving to the right on the breakpoint curve). Once dichloramine is formed, the reaction cannot be reversed to form monochloramine.

> In this situation, increasing chlorine after monochloramine has been formed can adversely affect water stability, increase nitrification and decrease the ability to maintain residual disinfectant in distribution systems.

Optimize your chloramination practices - What, where and why to measure

Free Chlorine

- Measure throughout your treatment process to ensure CT
- Measure free chlorine (residual, not dose) prior to ammonia addition to determine how much ammonia to add.
- Target will depend upon treatment process and necessary CT.

Free Ammonia

- Measure throughout your treatment process
- Purpose to determine location on the curve.
- Target 0.04 – 0.1 mg/L following
  - Free Ammonia is too high • Reduce NH3 • Increase Cl2

Monochloramine (and Total Chlorine)

- This is the target disinfectant for chloraminating systems measure at the entry point to distribution system
- Total residual = Monochloramine
- Establish target to achieve 1.0 mg/l in all areas of distribution system
- Before sending water to the distribution system if:
  - Monochloramine is too high • Reduce NH_3 • Reduce Cl_2
  - Total Chlorine dropped after Ammonia addition • Increase NH3 • Reduce Cl2
  - Total higher than mono and no free ammonia • decrease chlorine feed

pH

- Measure at the entry point and designated points in the distribution system
- Chloramines are more stable (long lasting) at higher pH.
- Nitrifying bacteria growth rate declines as pH increases, and declines significantly at pH's approaches 9 and above.

Nitrite and nitrate

- Measure at the source, entry point and designated points in the distribution system
- Important to determine if nitrification is occurring

What happens after chloramines are formed

After chloramines are formed, they begin to decay and release ammonia back into the water.

- As decay occurs, monochloramine is converting to dichloramine and then dichloramine begins to dissipate.
- As pH drops, the rate of dichloramine formation is more rapid and it lasts longer in the water. (Wahman 2017).
  - Note: Dichloramine is a precursor in formation of NDMA (Nitroso-dimethylamine). NDMA is a carcinogen that will likely be regulated in drinking water in the future.

MUST deal any free ammonia that may be present in the distribution system – the result of which is **nitrification**.

- Nitrification is the process where ammonia is broken down to form nitrite (MCL=1.0 mg/l) and nitrate (MCL=10.0 mg/l).

Dealing with nitrification

Limit nitrification:

- Control chloramination process
- Maintain monochloramine residual above 1.5 mg/L, AWWA M-56
- Increase flushing (directional flushing with scouring velocity),
- Decrease dead-ends in distribution system (looping mains and auto-flushers)
- Manage stored water (If you don't have capability to increase turnover, you need to plan to spend money on such things as mixers, altitude valves, electrically controlled valves, simple SCADA, etc.)
- Consider alternative disinfectants (e.g., chlorine dioxide), pH adjustment and biocides (jury still out).
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Effects if not controlled	
Chemical:	**Biological:**
Depletes Chlorine Residuals	Increase in HPC (If Tested)
Nitrites/Nitrates Increase	Formation of Ammonia Oxidizing Bacteria
pH & Alkalinity go Down	Formation of Nitrite Oxidizing Bacteria
Potential to Create Lead/Copper Corrosion	
Increased Chemical Usage	
Potential for Increased DBP Formation	

Considerations:		
Nitrifiers WILL develop especially in the presence of:	Opportunistic and WILL develop anywhere and everywhere:	Must DECREASE water age wherever and whenever possible:
High Ammonia	Raw Water Lines	Frequent Flushing
pH > 7	Aerator/Reaction Basin	Remove Tuberculation in Pipes
Warmer Temperatures	Clarifiers/Cones – Sludge Blanket	Water Storage Management
Sufficient Alkalinity, Oxygen and Nutrients	Filters/Softeners	De-Stratify Towers Deep Cycle Towers
	Storage Tanks	Reduce Excess Stored Water
	Distribution Piping	

If supplemental disinfection becomes necessary – Satellite systems take note

REMOTE CHEMICAL FEED LOCATIONS: Add Ammonia first, establish a SAMPLE POINT WELL DOWNSTREAM TO CHECK concentrations, THEN CHLORINE FEED, and another SAMPLE POINT WELL DOWNSTREAM TO CHECK effects.

- If good monochloramine residual present:
  1. TYPICALLY ADD AMMONIA FIRST – ADD upstream far enough to assure good mixing prior to next step.
  2. Provide Sample Point to measure ACTUAL FREE AMMONIA in the water – make sure target free ammonia is present to hit target monochloramine residual.
  3. ADD Chlorine to form monochloramine residual.
  4. May require 15 to 60 seconds mixing and reaction time downstream of chlorine feed before adding sample point for CHLORINE ANALYZER, or grab samples. If you have a little pump station – this means you have to tap the water main outside of the building, and run a line back into the building for proper sampling or to hook to an analyzer.

Why am I worried about this stuff (IEPA only asked about my plan not my data)?

If nitrification takes control, your system will lose disinfection residual which **WILL** lead to:

- Violation of State Disinfectant Residual Regulation
- TCR Violation of Federal/State Regulation
- Vulnerability to pathogens including Legionella and naegleria fowleri
  - Legionella at Illinois Veteran's Home in Quincy
  - Naegleria outbreaks in Louisiana and recently in Texas
    - Lake Jackson, Texas
- Potential LCR violations because of increased corrosivity of distributed water
  - Lead issues
    - Flint, Michigan

What can I do about it?

Develop a nitrification action plan, monitor and be ready to make corrections in treatment and distribution system:

- Measure free and total ammonia along with nitrite and nitrate in the distribution system to confirm the level of nitrification that is occurring.
  - In distribution, increase free Ammonia-N indicates monochloramine residual is being decayed and ammonia is being release.
  - If total Ammonia-N is decreasing, it is likely being "consumed" by Ammonia-Oxidizing Bacteria (nitrification is occurring).
- Measuring total chlorine along with monochloramine.
  - Will indicate the decay of mono to di prior to reverting to ammonia.
- Check pH.
  - Lowered pH will also indicate decay of mono.

MATH REFRESHER

Special Reminder- The pounds formula equation works directly if the chemical is 100% pure (such as chlorine gas). If the chemical is not 100% pure, divide the pounds of chemical by the purity percentage (in decimal form).

EXAMPLE 1

What is the feed rate (mg/l) if 10 lbs of chlorine gas is added to 500,000 gallons of water?

$$lbs/Day = (MGD)(mg/l)(8.34) \equiv mg/l = \frac{\text{lbs/Day}}{(\text{MGD})(8.34)}$$

$$mg/l = \frac{10\text{ lbs}}{(0.5\text{ MGD})(8.34)} = \frac{10}{4.17} = 2.398$$

EXAMPLE 2

What is the feed rate (mg/l) if 10 lbs of 12% Sodium Hypochlorite is added to 500,000 gallons of water?

$$lbs/Day = \frac{(MGD)(mg/l)(8.34)}{Purity\ (\%\ as\ a\ Decimal)} \equiv mg/l = \left(\frac{\text{lbs/Day}}{(\text{MGD})(8.34)}\right) * (Purity\ as\ a\ Decimal)$$

$$mg/l = \frac{\text{10 lbs}}{(\text{0.5 MGD})(8.34)} * .12 = \frac{10}{4.17} * .12 = .288$$

EXAMPLE 3

Over a seven-day period, a system produced 40,000 gallons of water. In that time period, the system used 41.64 liters of 5% NaOCl solution (w/v). What is the average chlorine dosage in mg/L?

Convert Liters of NaOCL solution to Gallons: 1 gallon NaOCl = 10 lbs

1 gallon = 3.785 liters: $Gallons = \frac{\text{Liters}}{\text{Liters/Gal.}} = \frac{41.64}{3.785} = 11.0$

$$lbs/Day = \frac{(MGD)(mg/l)(8.34)}{Purity\ (\%\ as\ a\ Decimal)} \equiv mg/l = \left(\frac{\text{lbs/Day}}{(\text{MGD})(8.34)}\right) * (Purity\ as\ a\ Decimal)$$

$$mg/l = \frac{\text{110 lbs}}{(\text{0.04 MGD})(8.34)} * .005 = \frac{110}{.333} * .005 = 1.65$$

EXAMPLE 4

The chemical feed rate is 40 mL/min of 0.25% NaOCl solution (w/v) and the flow is 35 gpm. What is the chlorine dosage in mg/L as Cl2?

Convert mL to Gallons: 1mL = 0.000264172 Gal. 1-gallon NaOCl = 10 lbs 1440 Minutes/Day

Convert feed rate to a 24-hour period: $(40) * (1440) * (.000264) = 15.21\ Gallons$

Convert flow rate to a 24-hour period: $(35) * (1440) = 50{,}400\ Gallons$

$$lbs/Day = \frac{(MGD)(mg/l)(8.34)}{Purity\ (\%\ as\ a\ Decimal)} \equiv mg/l = \left(\frac{\text{lbs/Day}}{(\text{MGD})(8.34)}\right) * (Purity\ as\ a\ Decimal)$$

$$mg/l = \frac{\text{15.21 (Gal)} * \text{10 (lbs)}}{(\text{0.0504 MGD})(8.34)} * .0025 = \frac{152.1}{.420} * .0025 = 0.905$$