FLORIDA RURAL WATER ASSOCIATION

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FRWA Whitepaper
Successful Chloramination Systems

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Disclaimer: FRWA DOES NOT RECOMMEND CHLORAMINATION! Ammonia is a waste product. It is counterintuitive to add a waste product to drinking water. Ammonia degrades water quality. We posit that chloramination is more problematic to deal with than either Trihalomethanes (THMs) or Haloacetic acids (HAA5s). *Cleaner drinking water is preferred over adding more chemicals.*

If you have chloramines, what makes for a successful chloramination experience? And why do chloramines work at one system and not another? We have seen many systems where chloramination works and those that fail to meet the disinfection by-product MCLs. There are essential elements to making chloramination work. Florida Rural Water Association has uncovered the things that separate the successes from the failures. All of these systems have raw water that's difficult to treat and continual disinfection by-product problems. In some cases it is attitude and attention toward chloramination, and in other cases it is willingness to keep tanks and distribution system clean and chlorine feed under control.

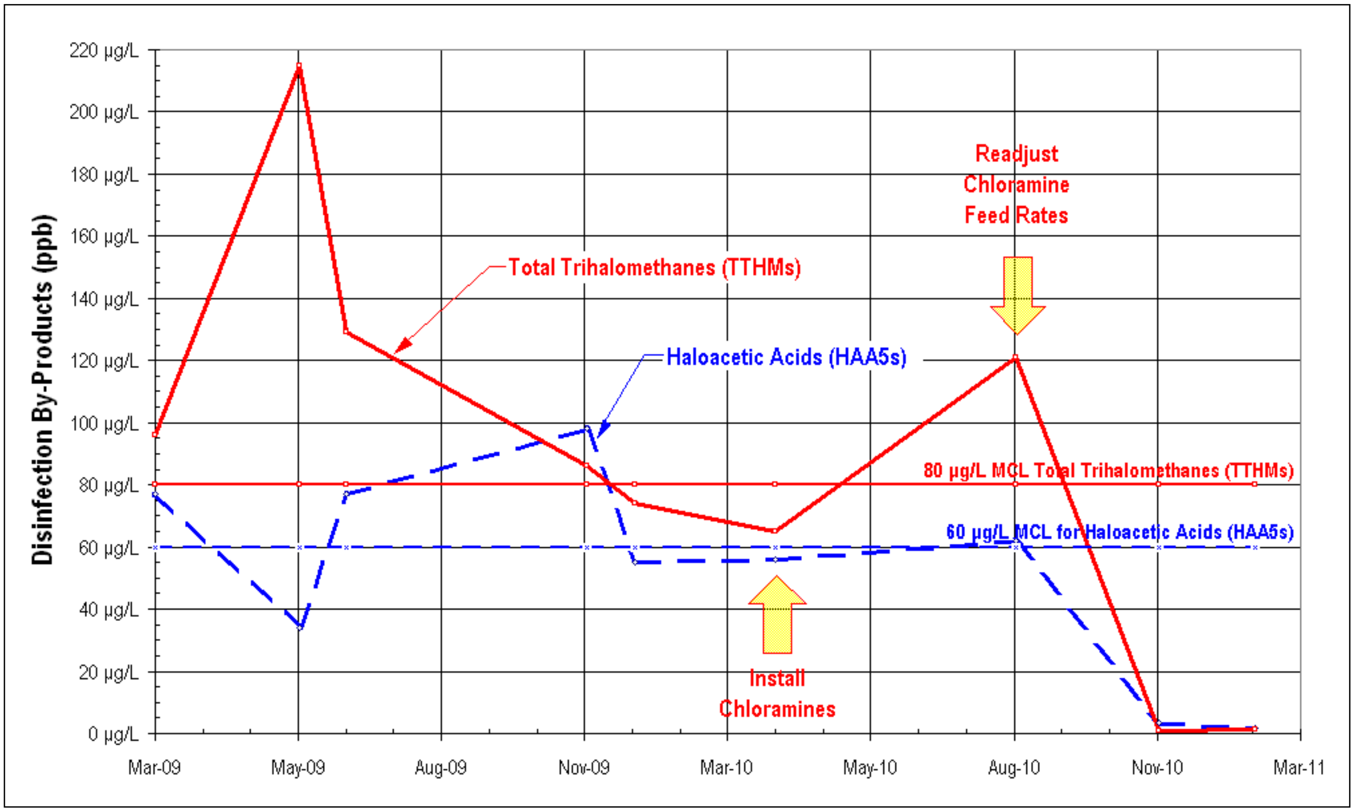

Figure 1 ~ Successful Control of Disinfection By-Products using Chloramines
(plus lower chlorine doses, systemic cleaning, and automatic flushing)

One of the recent successes involved a water system in north central Florida with total trihalomethanes above 150 ppb and haloacetic acids greater than 120 ppb. Following FRWA recommendations and Circuit Rider assistance they installed the chloramine feed system and systematically cleaned all sediment and biological matter out of their distribution system and tanks. They installed an automatic flushing program to keep the water fresh. After one false start (overfeeding ammonia), which was corrected by readjusting chemical feed pumps – the disinfection by-product levels dropped like a rock, see Figure 1.

The sure way to make chloramines fail is to adopt the attitude that chloramination is the silver bullet for disinfection by-products and a miracle of *'better treatment through chemistry'*. One cannot install ammonia feed and just walk away. There's more to it.

FRWA recommends improving drinking water quality over adding more chemicals, such as chloramination! Ammonia is a waste product. It is counterintuitive to add a waste product to drinking water. Ammonia degrades water quality.

If your system has chosen chloramines remember that it only one step toward controlling disinfection by-products – more work needs to be done.

When and Where Chloramines Work! We have seen many systems that have made chloramination work (and those that are not successful meeting the disinfection by-product MCLs). Below is a summary of common factors that contribute to make systems compliant.

1 **Water Age is your adversary. Avoid long detention times in large storage tanks.** Water, unlike wine, does not improve with age. Systems that are successful have done everything they can to lower water age and chlorine dosages in their storage tanks. These systems understand that large volumes of chlorinated water sitting out in the hot Florida sun for days and days cooks lots of unhealthy disinfection by-products. Heat and time are the enemies of good water.

Just last month, one system was encouraged to bypass its oversized tank by the FRWA Water Circuit Rider and use a secondary bladder tank in the interim. Before the test total trihalomethanes were 108 ppb and haloacetic acids were 107 ppb. They fell to 2.0 ppb TTHMs and 6.1 ppb HAA5s after the bypass test.

2 **Contact time is your foe. Move the chlorine point in the water treatment plant to lower contact time.** Successful systems have moved the point of chlorination downstream in their water treatment plants. These systems have found that they have a better chance of meeting the MCLs if fewer disinfection by-products are made in the water treatment plant.

Proven alternative oxidants to chlorine are available for pretreatment of iron, sulfides, and organic complexes to oxidize unpleasant color, odor, and taste -- all in accordance with published Best Management Practices (BMPs) as recommended in guidance documents and well-known industry practices.[1] One such guide is the USEPA's *Alternative Disinfectants and Oxidants Guidance Manual* it describes alternative disinfectants and disinfection techniques that can be used to comply with the Disinfectants and Disinfection Byproducts Rule (DBPR).

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1 USEPA. (1999). *Alternative Disinfectants and Oxidants Guidance Manual*. April 1999. USEPA Document No. 815-R-99-014. www.epa.gov/safewater. The manual describes alternative disinfectants and disinfection techniques that can be used to comply with both the stage 1 Disinfectants and Disinfection Byproducts Rule (DBPR) and the Interim Enhanced Surface Water Treatment Rule (IESWTR).

3 Dirty tanks increase chlorine demand and reduce water quality. Frequently Clean Storage Tanks. The systems that have recently cleaned (pressure washed) their storage / hydropneumatic tanks and flushed them out to remove debris, scaling, pitting, and biofilm growth produce fewer DBPs. Frequent tank cleaning decreases the potential of nitrification, biofilm regrowth and degraded water quality. A clean tank reduces chlorine demand.

Tank cleaning is required by FDEP Rule 62-555.350 (2), FAC. *“Finished-drinking-water storage tanks, including conventional hydropneumatic tanks ... shall be cleaned at least once every five years to remove biogrowths, calcium or iron/manganese deposits, and sludge from inside the tanks.”*

We recommend that systems with poor water quality clean, flush, disinfect and inspect all water tanks and treatment facilities more often or <u>every year</u>!

4 Bioslime, accumulations, and slit in water mains increase chlorine demand and reduce water quality. Aggressively Clean your Distribution System with Unidirectional Flushing.[2] Aggressively cleaning the distribution system contributes to better water quality and lower chlorine demands. Aggressive cleaning is much different than opening the occasional fire hydrant in response to a complaint. A unidirectional flushing program begins at the water source (wells) and systemically moves / cleans out to the extremities. Any other flushing constitutes removing a minor fraction of the debris and biofilm and stirring up turbidity in the surrounding areas increasing the potential of nitrification, biofilm regrowth and degraded water quality.

Successful systems understand that random flushing is not effective at cleaning the distribution system and producing higher quality water -- they know that sweeping in the middle of the floor does not get all the dirt. Unidirectional flushing is better than traditional flushing because it uses targeted, high-velocity water flow moving from source to hydrant in an outbound direction to scour the distribution system.

The American Water Works Association (AWWA) has prepared an exceptional DVD that outlines unidirectional flushing, “*Unidirectional Flushing; Enhance Water Quality and Improve Customer Relations*.” Unidirectional flushing uses targeted, high-velocity water flow moving from source to hydrant in an outbound direction to scour the distribution system. The DVD explains concepts and techniques of unidirectional flushing; how to develop a flushing plan using paper maps; how computer aided mapping simplifies the project; benefits verses traditional flushing techniques; and the benefits to consumers and the community.

5 Water Age is your enemy. Be Consistent and Regular by Flushing at Distribution System Extremities – install automatic flushing devices. The successful system uses automatic valves to keep the water fresh in all parts of the distribution system. This is more than paying lip service to flushing – we all live busy lives and tend to forget. Flushing should be consistent and regular and not when we find time, when we remember to, or get around to it.

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[2] Riess, et.al. (2010, March). *Unidirectional Flushing; Enhance Water Quality and Improve Customer Relations*. Opflow. AWWA.
Unidirectional Flushing DVD. AWWA. 2002. Catalog No. 64190.

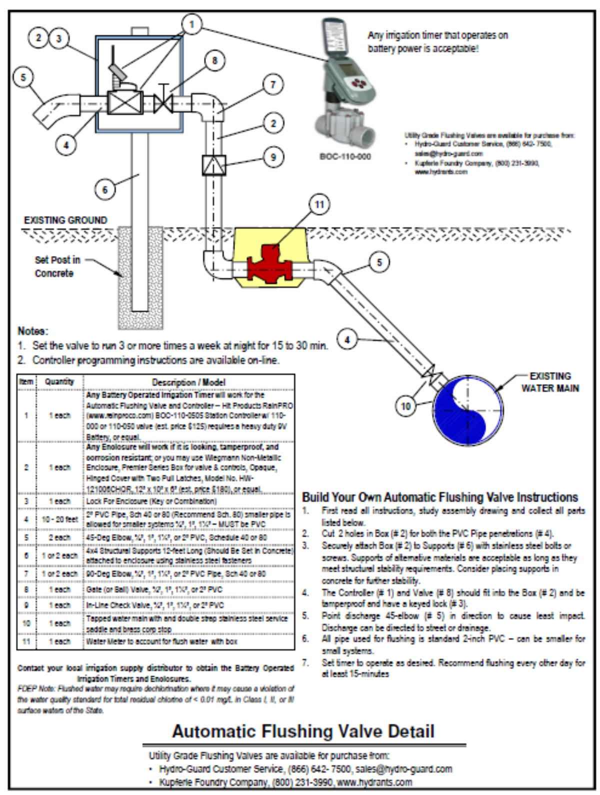
Successful systems assure that systematic and regular flushing occurs by installing automatic flushing devices on distribution system extremities and/or dead-end lines. Automatic flushing decreases the potential of nitrification, biofilm regrowth and degraded water quality.

We know that FDEP requires dead-end flushing only quarterly, per Rule 62-555.350 (2), FAC. *"Dead-end water mains conveying finished drinking water shall be flushed quarterly or in accordance with a written flushing program established by the supplier of water; additionally, dead-end or other water mains conveying finished water shall be flushed as necessary whenever legitimate water quality complaints are received."*

FRWA maintains that periodic flushing large volumes of water is not enough to keep the water fresh and chlorinated at dead-ends and extremities of the distribution system. More frequent flushing is better and uses much less water. The systems with chloramination and poor raw water quality ought to flush at the extremities and/or dead-end lines <u>weekly or every other day</u>!

Water systems may purchase utility grade devices that are commercially available for about $2,500 or construct their own automatic flushing devices for about $500. A good FRWA member shared the automatic flushing valve design shared with us and we are happy to pass it along to you. The **Build Your Own Automatic Flushing Valve** detail is available at no charge and by request from the FRWA water circuit riders or engineering staff, see Figure 2.

FRWA recommends systems install six or more of these devices on distribution extremities and can assist you in selecting appropriate locations for these units as well as flushing durations. Just send us a map of your water distribution system, we'll mark it up, and return it to you with recommended locations.



Utility Grade Flushing Valves are available for purchase from:
- Hydro-Guard Customer Service, (866) 642-7500, sales@hydro-guard.com
- Kupferle Foundry Company, (800) 231-3990, www.hydrants.com

Notes:
1. Set the valve to run 3 or more times a week at night for 15 to 30 min.
2. Controller programming instructions are available on-line.

Item	Quantity	Description / Model
1	1 each	**Any Battery Operated Irrigation Timer will work for the** Automatic Flushing Valve and Controller – Hit Products RainPRO (www.rainproco.com) BOC-110-0505 Station Controller w/ 110-000 or 110-050 valve (est. price $125) requires a heavy duty 9V Battery, or equal.
2	1 each	**Any Enclosure will work if it is looking, tamperproof, and corrosion resistant**; or you may use Wiegmann Non-Metallic Enclosure, Premier Series Box for valve & controls, Opaque, Hinged Cover with Two Pull Latches, Model No. HW-121006CHQR, 12" x 10" x 6" (est. price $180), or equal.
3	1 each	Lock For Enclosure (Key or Combination)
4	10 - 20 feet	2" PVC Pipe, Sch 40 or 80 (Recommend Sch. 80) smaller pipe is allowed for smaller systems ½", 1", 1½" – MUST be PVC
5	2 each	45-Deg Elbow, ½", 1", 1½", or 2" PVC, Schedule 40 or 80
6	1 or 2 each	4x4 Structural Supports 12-feet Long (Should Be Set In Concrete) attached to enclosure using stainless steel fasteners
7	1 or 2 each	90-Deg Elbow, ½", 1", 1½", or 2" PVC Pipe, Sch 40 or 80
8	1 each	Gate (or Ball) Valve, ½", 1", 1½", or 2" PVC
9	1 each	In-Line Check Valve, ½", 1", 1½", or 2" PVC
10	1 each	Tapped water main with and double strap stainless steel service saddle and brass corp stop
11	1 each	Water Meter to account for flush water with box

Contact your local irrigation supply distributor to obtain the Battery Operated Irrigation Timers and Enclosures.

FDEP Note: Flushed water may require dechlorination where it may cause a violation of the water quality standard for total residual chlorine of < 0.01 mg/L in Class I, II, or III surface waters of the State.

Build Your Own Automatic Flushing Valve Instructions
1. First read all instructions, study assembly drawing and collect all parts listed below.
2. Cut 2 holes in Box (# 2) for both the PVC Pipe penetrations (# 4).
3. Securely attach Box (# 2) to Supports (# 6) with stainless steel bolts or screws. Supports of alternative materials are acceptable as long as they meet structural stability requirements. Consider placing supports in concrete for further stability.
4. The Controller (# 1) and Valve (# 8) should fit into the Box (# 2) and be tamperproof and have a keyed lock (# 3).
5. Point discharge 45-elbow (# 5) in direction to cause least impact. Discharge can be directed to street or drainage.
6. All pipe used for flushing is standard 2-inch PVC – can be smaller for small systems.
7. Set timer to operate as desired. Recommend flushing every other day for at least 15-minutes

Automatic Flushing Valve Detail

Utility Grade Flushing Valves are available for purchase from:
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- Kupferle Foundry Company, (800) 231-3990, www.hydrants.com

Automatic Flushing Valve Detail — Sketch 1 of 6

Figure 2 ~ Automatic Flushing Valve Detail

The operational goal is to lower water age in the distribution system. The automatic flushers can be set to run 3 or more times a week at night for 15-30 minutes.

6 Substantially Reduce Chlorine Feed Rates.

The whole point of feeding chloramines is to control disinfection by-product production. At the s ame time chlorine use needs to be cut while maintaining the minimum combined chlorine residual.[3] Reduction of chlorine usage means reduced disinfection by-products!

Chlorine levels are often kept artificially high to avoid bacteriological issues and boil water notices. Operators have a daily concern about maintaining residuals; on the other hand disinfection by-

[3] Chlorine is, by far, the most commonly used disinfectant in the drinking water treatment industry and all water suppliers using chloramines are required to maintain a minimum combined chlorine residual of 0.6 milligram per liter throughout their drinking water distribution system at all times per FDEP Rule 62-555.320(12)(d), FAC.

product levels are only taken once every quarter or year. There is no immediate feedback when DBPs are created with higher than necessary chlorine levels.

The risk of bacteriological hits from lowered chlorine feed must be balanced against the busting of disinfection by-product MCLs. System operators and owners / managers must weigh the immediate and long-term ramifications of chlorine feed rates – this is what EPA means when they talk about a simultaneous compliance issue.

Disinfection by-products may have historically been an owner's long-range concern whereas residuals are more an operator's short-term issue. In successful systems the owner and the operator both understand the importance of keeping the chlorinator turned down as low as possible. These successful systems have determined that turning up the chlorinator is not necessarily a good thing; it may be just for operator convenience. Daily chloramine residual and bacteriological concerns (the total coliform rule) should not cause disinfection by-products compliance problems (the disinfection by-product rule).

7 **The Ammonia Feed System is Correctly Operated.** Successful systems understand that chloramine fed systems require operator expertise and understanding of the correct stoichiometry and maintenance of the injector and feed system. They understand that when the chlorine demand changes in the source water the ammonia feed system feed rate must be recalculated and readjusted.

FRWA has found with repeated experience that operational problems with chloramine systems are likely to include any or all of the following problems:

1. Modifications to the ammonia operational settings or installation that deviate from good practice, design, and theory.

2. Improper chlorine-to-ammonia ratios, stoichiometry, and feed calculations.

3. Incomplete and/or random distribution system flushing that leads to high water age.

4. Possible equipment malfunctions, such as chlorine or ammonia metering pumps or calcification of the ammonia injector. Ammonia injectors must be cleaned more frequently than chlorine injectors as they quickly foul up with calcium deposits.

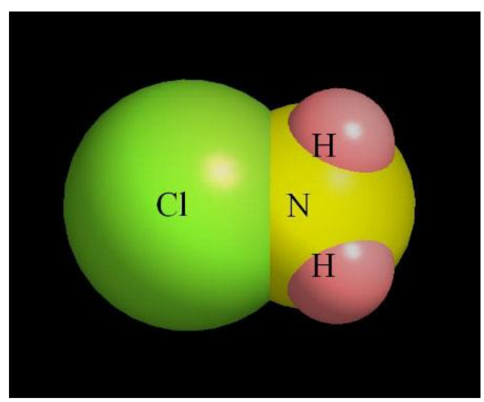

Figure 3 ~ Monochloramine, NH_2Cl

Another chloramine success story recently occurred with a system in the Miami/Dade area. It had a long history of disinfection by-product exceedances prior to our involvement. During a follow-up site visit it was found by the FRWA Circuit Rider that the chlorine-to-ammonia ratio was out of balance and the primary cause of the high disinfection by-products.

The circuit rider determined the correct stoichiometry ratio, which required: 1) finding the chlorine <u>residual</u> (not feed rate) and resetting the ammonia to the appropriate dosage; 2) determining the best ratio to produce the very stable monochloramine (NH_2Cl, see Figure 3) provides the; and 3) adjusting the ammonia pump based on the strength of the ammonia sulfate solution.

Monochloramine is produced when three to five parts of chlorine are feed to one part of ammonia – the most optimal range for chlorine-to-ammonia feed is 4.5 Cl_2 to 1 NH_3-N. It is easy to overfeed chlorine or ammonia, see the Chloramine Breakpoint Curve in Figure 4 below. When chlorine is overfed in relation to ammonia (stoichiometric ratios greater than 5 Cl_2 to 1 NH_3-N) dichloramine ($NHCl_2$) and trichloramine (NCl_3) compounds are produced; these do not provide adequate bacteriological protection, are ineffective at disinfection by-product control, and produce undesirable taste and odor. Although overfeeding chlorine is undesirable, overfeeding ammonia is worse and can greatly contribute to nitrification (stoichiometric ratios less than 2.5 Cl_2 to 1 NH_3-N).

The system was actually feeding about twice the recommended level of chlorine-to-ammonia (about 8 Cl_2 to 1 NH_3-N). The solution was simple – adjust the metering pumps to feed the correct ratios of chlorine and ammonia. This was done and the correct settings were recorded for future reference. When the system re-sampled the disinfection by-product levels fell -- total trihalomethanes which ranged 140 - 271 ppb fell down to 60 ppb and haloacetic acids went from 110 - 280 ppb down to 32.5 ppb.

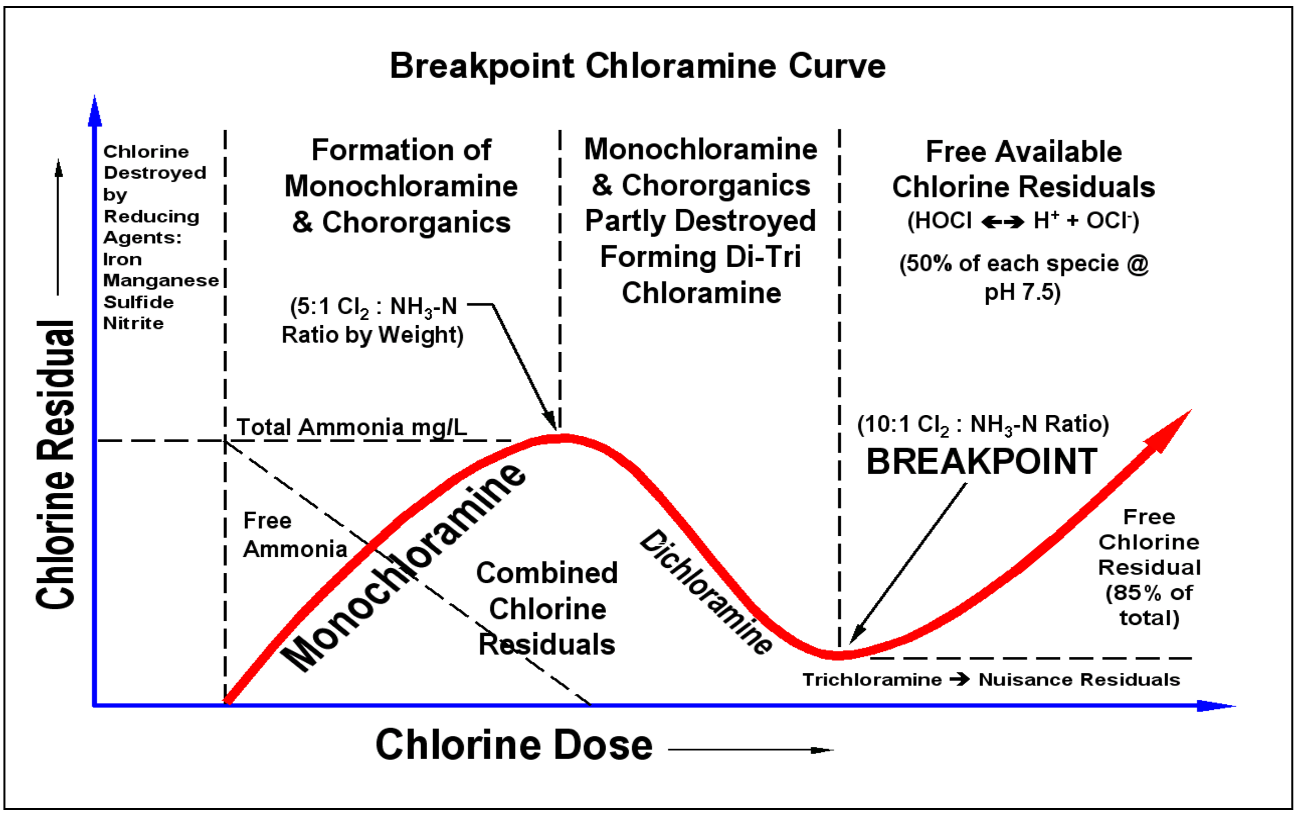

Figure 4~ Chloramine Breakpoint Curve

This real life experience demonstrates that chlorine and ammonia ratios have a significant impact on returning the disinfection by-product levels within the MCL. Some "tweaking" of the chemical feed rations will still be necessary, as it is apparent to the circuit rider and operator that the levels must be further reduced as the Florida summer sun heats up.

8 **Periodic Free Chlorine Burning Reduces Potential Nitrification.** Systems successful in controlling nitrification and keeping chloramine demands down periodically convert to full strength free chlorine. This is necessary to kill the biofilm and autotrophic nitrifying bacteria. Often called “burning”, the length of time for free chlorination starts at a couple of days or longer with the proper notifications to customers and the local FDEP office per Rule 62-555.350(10)(c), FAC. Chloramines have a tendency to break down in the distribution system given long residence times.

We received a call from a central Florida water system asking for help with numerous odor complaints. Customers were calling about hydrogen sulfide (rotten egg odor) coming from their taps and the operator was unable to keep chlorine residuals even though they doubled feed rates. After quizzing the operator some more we discovered that the system had installed chloramines three months prior and the system had never flushed. It was determined that a full-blown nitrification event was occurring. We recommended that ammonia feed be temporarily discontinued and switch to raised levels of free chlorine for two or three weeks along with customer and FDEP notifications. The raised chlorine levels should accompany aggressive flushing prior to returning to chloramines.

Stepwise Approach for Disinfection By-Product Reduction. Successful Chloramine Systems use a stepwise approach to reduce disinfection by-products – a combination of methodologies in addition to chloramines. The objective is to begin with effective / inexpensive measures first and work toward more extensive / expensive changes. The hierarchy of approach begins with low cost operational changes and moves to new treatment units. Figure 5 below outlines the time-tested approach. ***Each system that has carefully followed these recommendations has been successful in lowering DBPs!***

1. Initiate Chlorination Changes (move chlorine point)
2. Clean / Flush Tanks & Distribution System
3. Install Automatic Flushing Valves
4. Lower Chlorine Dose and Residual Rates
5. Seriously Consider Alternative Disinfection and New Treatment Units (GAC, MIEX, RO, etc.)
6. LAST OPTION Consider Chloramination

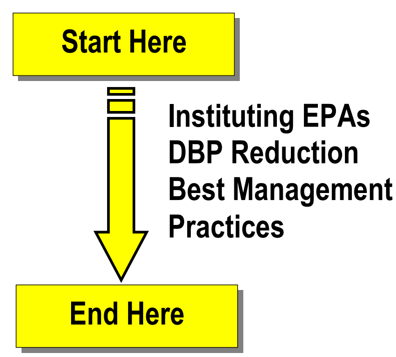

Figure 5 ~ Stepwise Approach for DBPs Reduction

One Final Chloramine Success Story. A system called to complain about their flushing program results. Disinfection by-products went up instead of down. Total trihalomethanes were at 95 ppb before flushing and 145 after! As we talked, the whole story became clear. The system only flushed just before taking the quarterly samples and they flushed starting 24-hours before sampling. This was a case of, *"If two aspirins make me feel better, then how about the whole bottle?"* Only part of the message was received and implemented.

The system had made no other changes – the tanks were not cleaned, the water system was still coated with biofilm and laden with debris as before, chlorine dosage was the same, the chlorination point was not moved, and they had no automatic flushing devices.

We were able to explain that too much of a good thing sometimes produces bad results. Flushing only before sampling stirs up the sediment in the tank and mains, making the water more turbid, and water quality worse.

The system followed our recommendation and did all that we suggest and disinfection by-products went down, this time to one-third of the previous levels!

To answer the questions:

f you have chloramines, what makes for a successful chloramination experience? Chloramines are successful when operators and owners realize that *chloramination is only the first step in a multi-step process* to substantially limit the formation of disinfection by-products in the water treatment plant and out in the distribution system. The water system from the well to the last customer needs to be as clean as possible and flushed weekly. Chlorine dosages need to be as low as possible. The operator and owner must have a firm understanding of the simultaneous compliance issues and chlorine-ammonia chemistry.

And why do chloramines work at one system and not another? Chloramination by itself cannot completely control disinfection by-products and lack of proactive operation is a sure way to make it fail.

We would like to add that if you follow the **Stepwise Approach for DBPs Reduction you may not need CHLORAMINATION in the first place!**

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SIDEBAR 1

FRWA Recommends Against Chloramines as First Choice. When considering alternatives for disinfection by-product control, we recommend water professionals first seriously focus on cleaning up the water before chlorination and then keeping the distribution system and tanks as clean as possible. Better water treatment means a fresher product delivered to customers. It is counterintuitive to add ammonia (a pollutant) to drinking water and as a result FRWA has not been encouraging chloramination, but will help any system that chooses it as long as they are willing to aggressively clean and flush their system.

So it is VITAL to remove any and all sediment and biological matter from the hydropneumatic tank and water mains before installing the ammonia feed system. This is a multi-step process – forget one step and problems are likely to occur and chlorine dosages cannot be lowered adequately to comply with the disinfection by-product rule.

Without a continual and systematic flushing program water out in the distribution system will grow old, chlorine levels drop, and biofilm bacteria is allowed to multiply out of control. This change in water chemistry is the ideal environment for nitrification - nitrosomonas and nitrobacters.

Chloramines produce fewer disinfection by-products and they have not been the subject of EPA's attention and may be regulated sometime in the future. And as a result reliance on chloramines may be short-lived and closely regulated by EPA as trihalomethanes and haloacetic acids.

SIDEBAR 2

Background Information on Chloramines.[4] Chlorine has been safely used for more than 100 years for disinfection of drinking water to protect public health from diseases, which are caused by bacteria, viruses, and other disease causing organisms. Chloramines, the monochloramine form in particular, have also been used as a disinfectant since the 1930's. Chloramines are produced by combining chlorine and ammonia. While obviously toxic at high levels, neither pose health concerns to humans at the levels used for drinking water disinfection.

Chloramines are weaker disinfectants than chlorine, but are more stable, thus extending disinfectant benefits throughout a water utility's distribution system. They are not used as the primary disinfectant for your water. Chloramines are used for maintaining a disinfectant residual in the distribution system so that disinfected drinking water is kept safe. Chloramine can also provide the following benefits:

- Chloramines are not as reactive as chlorine with organic material they produce substantially lower concentrations of disinfection byproducts in the distribution system.
- Because the chloramine residual is more stable and longer lasting than free chlorine, it provides better protection against bacterial regrowth in systems with large storage tanks and dead-end water mains.
- Chloramine, like chlorine, is effective in controlling biofilm, which is a slime coating in the pipe caused by bacteria. Controlling biofilms also tends to reduce coliform bacteria concentrations and biofilm-induced corrosion of pipes.
- Because chloramine does not tend to react with organic compounds, many systems will experience less incidence of taste and odor complaints when using chloramine

[4] USEPA. Background Information on Chloramines. http://www.epa.gov/region9/water/chloramine.html

SIDEBAR 3

What Factors Increase Disinfection By-Products?

Disinfection by-products are formed when chlorine reacts with organic materials (tannins, etc.). Organic materials are found in the source water and biogrowth / debris in the distribution system and storage tanks. The measure of organic materials in water treatment is known as Total Organic Carbon (TOC). When TOCs are greater than 5 mg/L disinfection by-product formation becomes a concern for systems trying to meet the Disinfection By-Product MCLs – systems over 9 mg/L TOC have chronic DBP problems without treatment.

Disinfection by-product creation is accelerated by the following conditions:

- High chlorine dosage rates
- Long reaction times or high water age
- High temperatures
- High organic material content (TOC greater than 5 mg/L)
- pH – more trihalomethanes are created with high pH and more haloacetic acids with low pH waters
- If the system has higher levels of haloacetic acids than trihalomethanes the chlorine dosages have been found to be excessive – much more chlorine is being used than is prudent.

FRWA experience with dozens of water systems has shown that excessive chlorine dosages push the disinfection by-product reaction to the extreme. Trihalomethanes are created and then destroyed, forming additional haloacetic acids. FRWA has found these conditions frequently occur when water system is operated by part-time personnel or contract operators -- operators tend to turn the chlorine up to avoid bacteriological issues and raise residuals (short-term operational issues), without concern about exceeding the disinfection by-product MCLs (a long-term treatment issue).

Different disinfectants produce different types or amounts of disinfection byproducts. Disinfection byproducts for which regulations have been established have been identified in drinking water, including trihalomethanes, haloacetic acids, bromate, and chlorite.