Chloramine Production & Monitoring in Florida's Water Supply Systems

Robert D. McVay

Robert McVay, P.E., is the drinking water trainer for the Florida Rural Water Association. His duties include assisting water treatment systems that experience disinfection byproduct problems and troubleshooting small- and medium-size water treatment plants in Florida. This article was presented as a technical paper at the FSAWWA Fall Conference in November 2007.

Source waters in many areas of the state contain elevated levels of total organic carbon (TOC) which combines with free chlorine to produce disinfection byproducts (DBPs). These compounds are regulated at 80 parts per billion and 60 parts per billion for total trihalomethanes and haloacetic acids. Meeting these low regulatory limits can be difficult when free chlorine is used as a disinfectant.

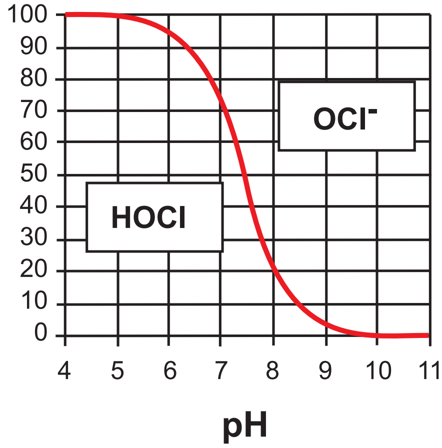
With the increase in regulatory attention such as the new Stage 2, Initial Distribution System Evaluation, rules that require all public water supply systems to report elevated DBP values, and given the problems meeting current rules, many water treatment systems have elected to switch to chloramines as their secondary disinfectant.

Chloramination, or producing chlorine by adding ammonia in the presence of free chlorine, has been used by many water treatment systems for a number of years for controlling the production of DBPs. The process of forming chloramines is well understood and consists of adding ammonia in the presence of free chlorine in a ratio of about 3-5 milligrams per liter (mg/l) free chlorine to 1 mg/l of ammonia.

Unfortunately, switching water systems from free chlorine to chloramine creates new and unexpected problems. Attempting to find an explanation for what is occurring is not easy, and when problems grow worse, the system operator is left with no other option than to switch back to free chlorine disinfection and performing a "burn."

A burn is a process that lasts several weeks, during which superchlorinating with free chlorine is used to destroy problematic organisms and unstable conditions in the water system. When this happens, DBPs often exceed regulatory limits, sloughing of pipeline growth and sediments can occur, and customers receive high concentrations of chlorine, often resulting in taste and odor complaints.

Figure 1



Fortunately, the use of chloramines and the control of problems in the distribution system follow predictable patterns that can be identified and corrected before conditions deteriorate to a point where problems occur. This article examines the concepts in the formation and the use of chloramines and suggests pre-emptive techniques to identify the status of deteriorating conditions and implement corrective actions to keep the chloramination process under control. The work supporting these recommendations was performed in a Florida Department of Environmental Protection-sponsored study for the Lake City Florida Water System conducted in 2008.

Understanding Chlorine Addition for Primary Disinfection

DBPs are formed when chlorine, in the form of hypochlorous acid formed in the disinfection process, is allowed to contact naturally occurring organic material. To control the production of DBPs effectively, three methods can be employed:

1) Remove the organic precursors that are reactive with the chlorine.
2) Decrease the amount of hypochlorous acid available for the reaction.
3) Decrease the time of contact between the organic material and the acid.

Generally, operators will accomplish all these objectives by moving chlorine dosing points to locations that allow some precursor removal to occur within the plant and then lower free chlorine concentrations to only those levels needed to meet regulatory requirements.

When in-plant strategies are not successful, many systems have chosen to reduce the amount of hypochlorous acid available for reaction within the distribution system by switching to chloramine as a secondary disinfectant. Free chlorine or other disinfectant is used to provide primary disinfection and meet initial disinfectant demand, and chloramine is used as the secondary disinfectant, i.e., in the distribution system. The purpose of secondary disinfection is to provide enough disinfectant to prevent bacteriological growth.

It is useful to review the mechanisms of how free chlorine and chloramines are made in the disinfection process. When free chlorine (Cl_2) is initially added to water, it goes through a series of chemical actions and eventually splits into two components: hypochlorous acid (the active compound that forms the DBPs) and the hypochlorite ion.

Although both hypochlorous acid and the hypochorite ion provide disinfection, the hypochorous acid that is formed is much stronger than the ion. The amount of hypochlorous acid or the hypochlorite ion formed is completely dependent on pH. These relationships are shown in Figure 1.

As can be seen from the curve, when the pH of the water is around 7.5, a value near most Florida groundwaters, the relative concentrations of hypochlorous acid is around 50 percent. If pH is lowered, more hypochlorous acid is available and more DBPs form at a faster rate.

Conversely, when pH is increased, the available hypochlorous acid is lower and DBP formation will be slower. As the pH approaches 8, the relative portion of the hypochlorous acid is about 20 percent.

Above a pH of 9, most of the chlorine is in the form of the less effective hypochlorite ion, and disinfectant ability will be about 1 percent of the disinfectant power compared to the acid form. Raising pH does have a significant drawback: As the amount of hypochlorous acid is reduced, disinfection ability is reduced accordingly.

The practical significance of this fact in

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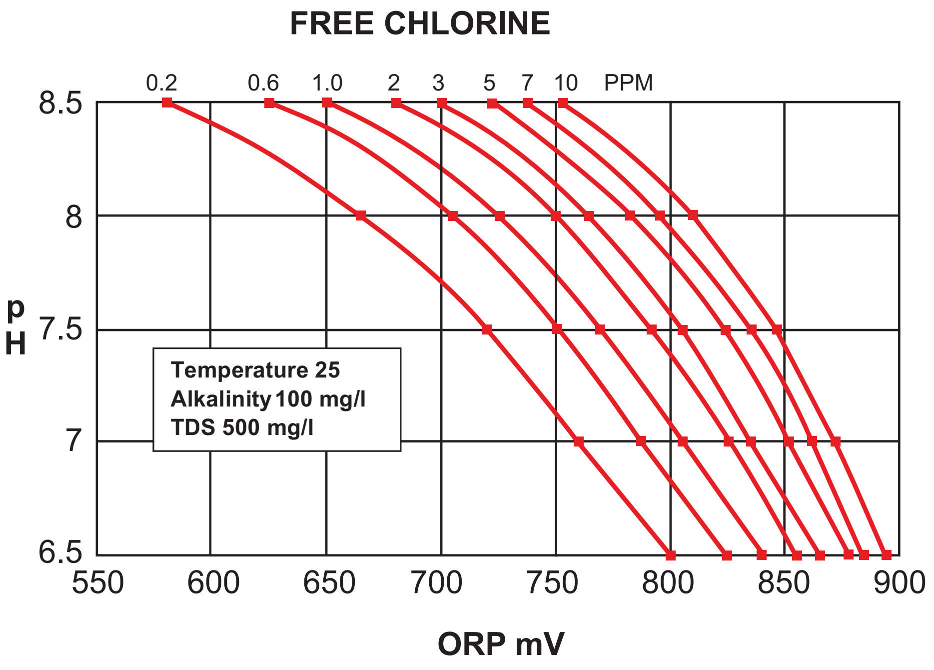

Figure 2: Breakpoint Chlorination Curve and Chloramine Development

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water treatment is that free chlorine residual does not indicate microbial inactivation unless pH is accounted for. This limitation can be avoided when the hypochlorous acid component is measured directly, which can be accomplished by the use of an ORP meter.

An ORP meter will provide an estimate of the inactivation power of chlorine at any given pH. An ORP value of 650 mV has been used since mid-1980 for municipal drinking water in Europe to maintain high oxidative conditions in water distribution systems.

Figure 2 illustrates how this value relates to current Florida Department of Environmental Protection residual requirements for free chlorine in a water distribution system. At ORP values between 500 and 600 mV, bacterial inactivation will occur but it will require much longer contact time to be effective.

To understand how chlorine forms DBPs with a source water that contains chlorine-demanding substances, it is necessary to develop a breakpoint chlorination curve. An example is illustrated in Figure 3, where the X-axis shows the amount of free chlorine added continuously to a source water sample and the Y-axis shows the total chlorine residual present.

Total chlorine is in a combined form (Y axis) until all the inorganic and organic demand is satisfied. In other words, until the initial inorganic demand has been oxidized, no hypochlorous acid is available for organic reactions.

The reactions shown on the breakpoint curve are unique for each water system, but they follow the general pattern illustrated in Figure 3. Note that between the segments labeled 1 and 2, free chlorine has been added but no chlorine residual of any kind is shown on the left Y-axis because within this range, the chlorine is reacting with inorganic constituents in the water such as iron, manganese, hydrogen sulfide, and any ammonia that may be naturally present.

This oxidation-reduction reaction will proceed to completion until all inorganic substrate is consumed. Within this range, free chlorine may be added to the water without producing any significant DBPs. This concept is important because many Florida water sources contain iron, hydrogen sulfide, and background ammonia—all inorganic-demanding substances that can be oxidized with chlorine without producing significant DBPs.

Between segments 2 and 3, there are no longer any unreacted inorganic compounds in the water, and oxidation of organic contaminants that produce DBPs will now occur. To prevent this undesirable situation, many water treatment plants with DBP problems have switched to the use of chloramines. Chloramine is produced by adding 1 mg/l ammonia to a ratio of between 3 mg/l to 5 mg/l measured free chlorine.

Note that when the chlorine to ammonia ratio exceeds about 5 mg/l chlorine to 1 mg/l ammonia, the production of other chloramine products besides monochloramine occurs simultaneously with a decrease in the measured total chlorine residual concentration. These reactions result in additional chlorine demand. Note that when the 5:1 ratio is exceeded, monochloramine (NH_2Cl) is being converted into dichloramine ($NHCl_2$), and finally as more chlorine is added, the dichloramine is converted to nitrogen trichloride before off gassing as nitrogen.

The most desirable form of chloramine is

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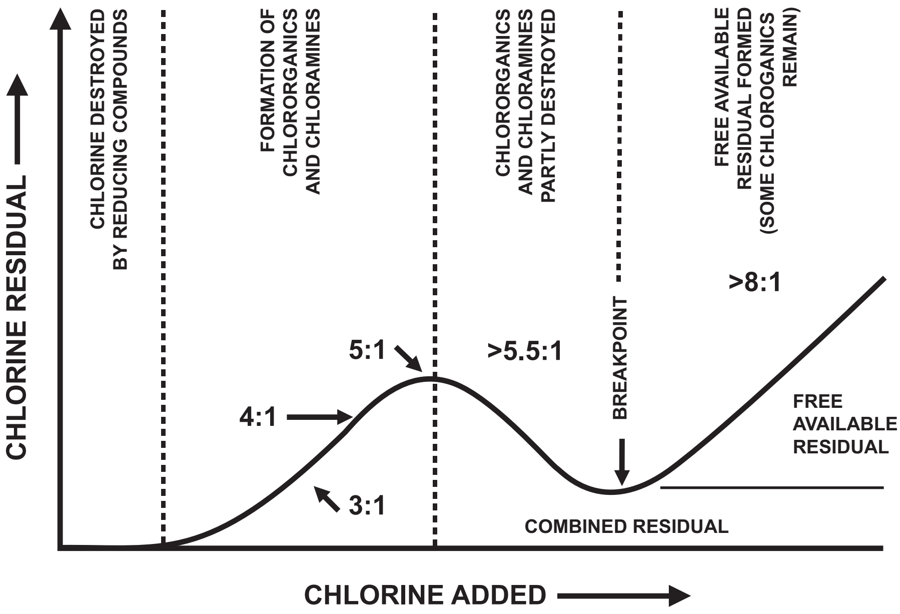
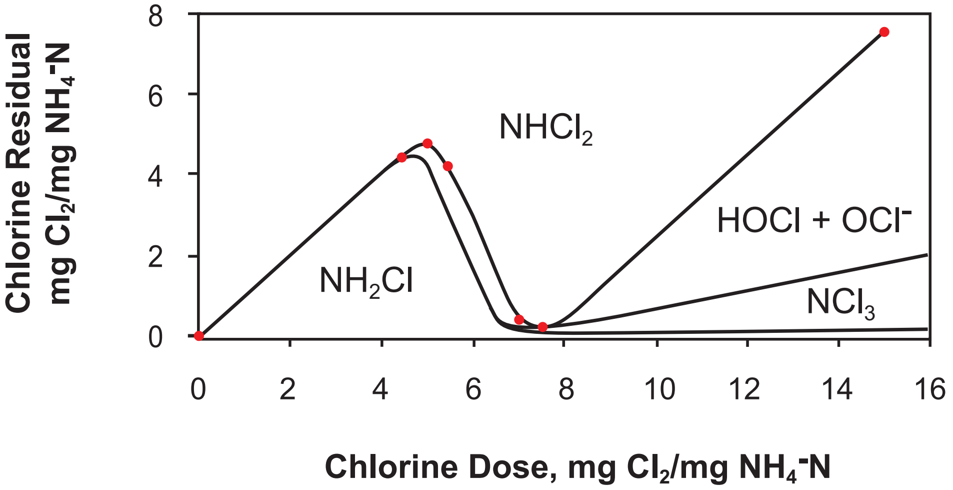


Figure 3: Breakpoint Chlorination Curve Showing affects of Various Chlorine-to-Ammonia Ratios

Figure 4: Production of Various Species of Chloramine by Increasing Chlorine Doses



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monochloramine (NH_2Cl) and it will predominate below the 5:1 free-chlorine-to-ammonia ratio. As the amount of free chlorine exceeds the 5:1 ratio, dichloramine is produced and the total chlorine residual will fall off approaching zero total residual at point 4 on the breakpoint curve.

If additional free chlorine is added beyond point 4 on the curve, then "breakpoint," or the point where free ammonia will be released to the atmosphere, will be reached. The figure shows that breakpoint chlorination is reached at a ratio of free chlorine to ammonia at a ratio of about 10:1, resulting in the formation of nitrogen gas, nitrate, and nitrogen chloride, as well as hypochlorous acid and the hypochlorite ion.

Point 4 on the curve represents the point where free chlorine or hypochlorous acid and the hypochlorite ion can be measured in a water treatment plant or in a water distribution system as free chlorine. When chloramine is used as a secondary disinfectant, hypochlorous acid is not present.

It is important that the chlorine be added prior to the ammonia. Ammonia is a nutrient, and adding it to water prior to the chlorine will encourage biological growth and bacterial resistance to the added disinfectants.

When ammonia is added to water containing hypochlorous acid, the production of chloramines occurs instantaneously with the rate of reaction controlled by pH. The reaction rates are shown in Table 1. The arrow indicates the range of Florida source waters that are typically between a pH of 6.8 and 7.8. In this range, chloramine production is instantaneous.

Determining Chlorine Demand for Your Water System

It is imperative that water systems identify their chlorine demand so free chlorine dosage can be minimized at the plant and chlorine residuals can be maintained in the distribution system at the 0.20 mg/l free chlorine or 0.60 mg/l chloramine levels required by the state of Florida.

When performing DBP analysis on their finished water at the plant, operators at many systems find that after implementing the controls described above, DBPs produced at the plant are at least 25 percent less than those produced in the distribution system. Excessive free chlorine residuals in the distribution system increase the reaction rates with organic material and thus produce more DBPs. Conversely with chloramine, if significant excess residual is not maintained, the chloramine will have a tendency to break down, which can lead to loss of disinfection ability, the formation of DBPs, slime growth, and nitrification.

The substances that cause disinfectant demand are indicative of the source water quality. These are also the compounds that typically cause water quality customer complaints. Most source waters contain a variety of both inorganic and organic contaminants whose chlorine demand can be identified with a simple jar test without knowledge of the types of concentrations of the contaminants.

A disinfection "jar test" is a simple procedure in which a known concentration of chlorine, such as the approximate 5.25 percent household bleach, is used to make a chlorine dosing "standard." To facilitate calculations, add 5 ml of the bleach to 1 liter of de-ionized water to make an approximate 200-mg/l standard solution. Check the concentration of the standard by adding 5 ml to 1 liter if de-ionized water. The free chlorine concentration should register on a DPD meter near 1 mg/l free chlorine.

Once the standard's concentration is determined with the meter, it can then used to dose 1-liter source water samples in 2.5-ml, 5-ml, and 10-mg/l increments. The combined and free residual chlorine levels are then measured after 15 minutes to develop the classic breakpoint chlorination curve.

The chlorine demand test will provide the operator with a good estimate of the chlorine-demanding substances that are available immediately and will identify the minimum chlorine dose that can be added to achieve breakpoint. This is important because excessive chlorine being added will increase the production of DBPs within the treatment plant.

Estimating Chlorine Demand Using Known Contaminant Concentrations

Chlorine demand also can be estimated

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Table 1: Time to 99 Percent Conversion of Chlorine to Monochloramine

	pH	Time (seconds)
	2	**421**
	4	**147**
→	**7**	**0.2**
	8.3	**0.069**
	12	**33.2**

Table 2: Determining Chemical Demand from Source Water Laboratory Analysis

Chemical Constituent (mg/l)	Col. A Multiplier	Col. B Source Water Concentration (mg/l)	Col. A x Col. B Chlorine Demand (mg/l)
Fe	0.64		
Mn	1.3		
H_2S	2		
NO_2	5		
NH_3	12		
Org-N	1		
TOC	0.1		
Total			

Oxidant	E° Volts
Hydroxyl Radical	2.85
Ozone	2.08
Hydrogen Peroxide	1.78
Permanganate	1.68
Hypochlorous Ion	1.64
Hypochlorous Acid	1.48
Monochloramine	1.40
Dichloramine	1.34
Oxygen	1.23

Table 3: Oxidative States of Common Oxidants Used in Water Treatment

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by using the laboratory or field sampling kit values for eight contaminants that are significant in demanding chlorine: iron, manganese, hydrogen sulfide, ammonia, organic nitrogen, nitrite, and total organic carbon (TOC). Table 2 illustrates how to use these laboratory values to determine chlorine demand.

This method provides a quick check on the chlorine demanding-substances. Note that the demand exerted by very small concentrations of naturally occurring ammonia is extremely high and will dominate the demand for free chlorine. It is not uncommon for Florida source waters to contain some measurable ammonia.

Also note that the demand for organic substances is typically less than 10 percent of the demand total and can be estimated by using a representative value of 5 mg-C/l for TOC if unknown. Organic nitrogen can be ignored when evaluating groundwater.

Chloramine Disinfectant Mechanisms

The ability of chloramine to inactivate pathogens begins to degrade relatively early in a distribution system. This process occurs within a few days after the monochloramine is applied and is known as autodegradation.

For each 3 moles of monochloramine degraded, 1 mole of ammonia will be released. The degradation will continue to occur the longer the chloramines are detained. This is the reason that water systems are encouraged to flush.

If organic material is present in the distribution system, chloramines will oxidize organic contaminants in the water, releasing ammonium. Both autodegradation and organic reactions favor the start of nitrification because ammonia is released into the distribution system.

Natural Degradation of Monochloramine (NH_2Cl)

Three degradation equations for monochloramine that occur in any water system are shown below. Note that in each case that the end product is either ammonia or the ammonium ion that both contribute to nitrification.

Equation #1: Autodecomposition
$3NH_2Cl \rightarrow N_2 + \mathbf{NH_3} + Cl^- + 3H+$

Equation #2: Oxidation of Organic Matter
$.1C_5H_7O_2N + NH_2Cl + .9H_20 \rightarrow$
$.4CO_2 + .1HCO_3^- + 1.1\ \mathbf{NH_4^-} + Cl^-$

Equation #3: Reduction by Nitrite
$NH_2Cl + NO_2^- + H_20 \rightarrow \mathbf{NH_3} + NO_3^- + HCl$

All of these forms of degradation of monochloramine are exacerbated by long detention times such as in dead-end pipes or in storage tanks. Most water system operators do not know the residence times in their distribution systems. Studies have found that many average-size water distribution systems have residence times that exceed 12 days in some places. In some smaller systems, residence times as high as 24 days are not uncommon. These residence times are more than adequate to favor monochloramine degradation.

Since the mechanisms of the degradation of chloramine are well known, it is recommended that water distribution systems target a 2.5-mg/l level in stagnant areas of the distribution system to avoid the problems discussed previously. When 2.5 mg/l of monochloramine is maintained, it has been found to impede nitrification significantly.

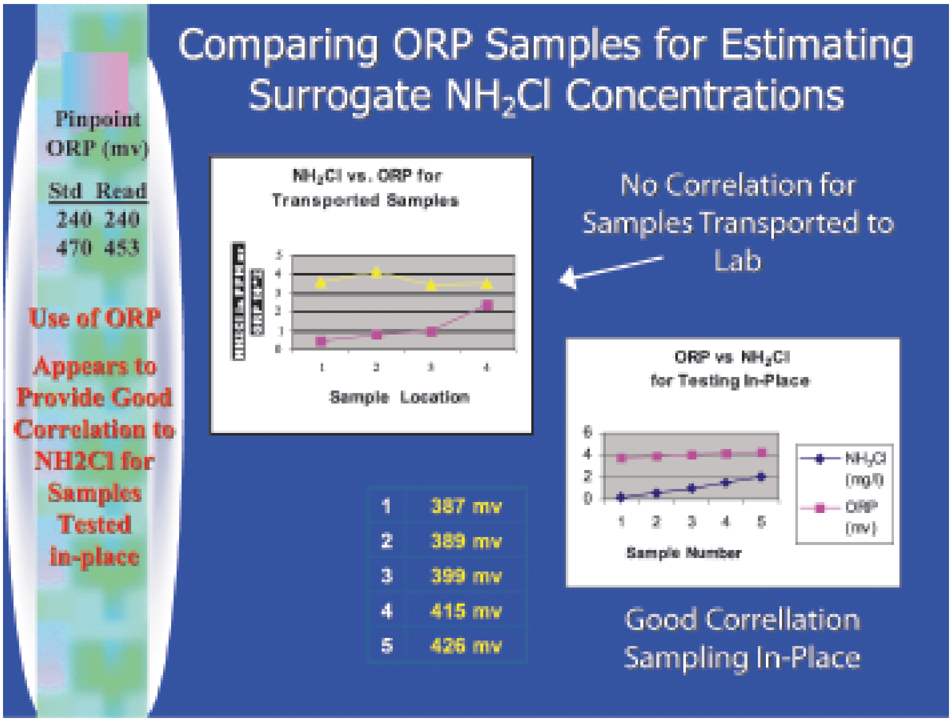
Monitoring Chloramine Levels in Water Distribution System

Monitoring chloramine residuals is essential to avoid loss of disinfection, nitrification, and biofilm growth in the distribution system. Direct measurement of free chlorine and total chlorine residual is always the preferred method of determining the concentrations and the type of disinfectants present, but it does not necessarily identify a problem condition unless other indicators are present.

Conventional methods of identifying chloramine breakdown and nitrification episodes include noting reduced disinfection residual; DO depletion; reduction in pH and alkalinity; the presence of ammonia, nitrate, and nitrite; and the increased growth of heterotrophic bacteria. Unfortunately, identification of these constituents are all indicators that a problem is in progress and possibly out of control, so more predictive methods must be employed as are discussed in the following paragraphs.

Maintaining a Highly Oxidative (ORP) Environment in a Water Distribution System

Nitrification is unlikely at high oxidative states, since these states tend to inhibit the or-



Comparing ORP Samples for Estimating Surrogate NH_2Cl Concentrations

Pinpoint ORP (mv)

Std	Read
240	240
470	453

Use of ORP Appears to Provide Good Correlation to NH2Cl for Samples Tested in-place

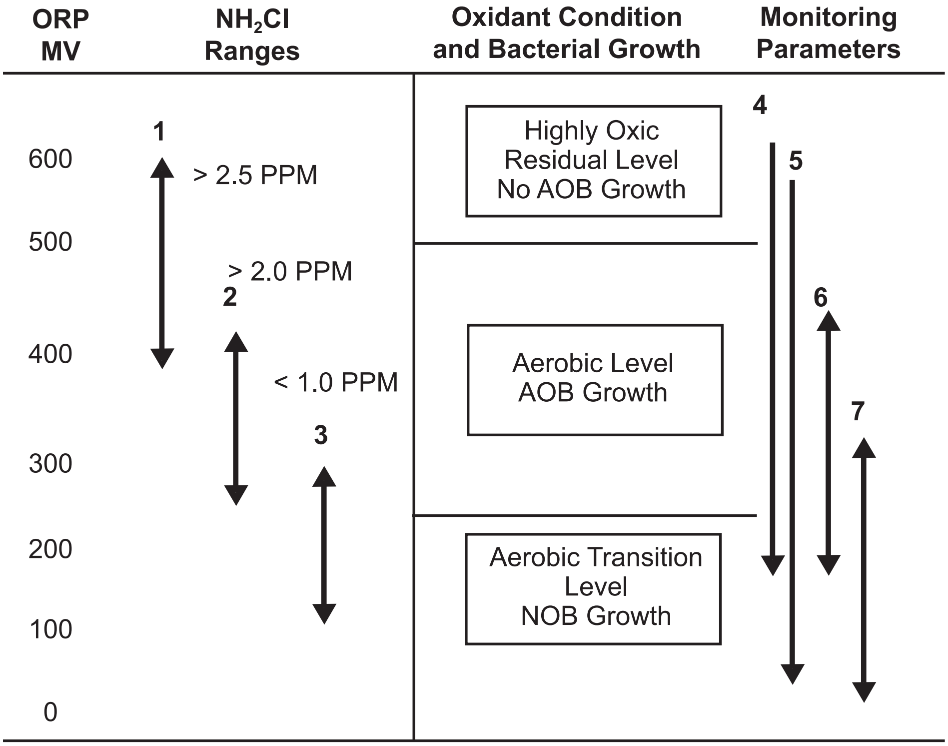
No Correlation for Samples Transported to Lab

1	387 mv
2	389 mv
3	399 mv
4	415 mv
5	426 mv

Good Correllation Sampling In-Place

Figure 5

Figure 6: ORP Values for Chloramine Degradation in a Water Distribution System



1. Desired ORP Range to inhibit Nirtrification.
2. ORP Range Supporting Nitrification and Growth of AOB.
3. ORP Range Where Nitrification is Occurring and NOB Supported.
4. Drop in DO level indicating conditions for Nitrification or Nitrification may have started.
5. Drop in pH/alkalinity level indicating that Nitrification is imminent or beginning.
6. Detection of NH_3 in this range indicates that Nitrification Process has begun.
7. Detection of NO_2 in this range indicates Mature Nitrification Process.

Note: Monitoring Parameters (4, 5, 6 and 7) are useful relative to initial ORP signature.

The upper range of chloramine residual suggested (2.5 mg/l) inhibits bacterial activity; amounts of chloramine below these levels are in a range where bacteria can grow with less inhibition.

ganisms necessary for the process to occur. To minimize microbial growth, therefore, high oxidative, or ORP, states should be maintained as previously discussed.

All disinfectants used in water treatment inactivate microbes by oxidation. Each disinfectant used in water treatment has a relative oxidation potential that increases the oxidative state beyond the level possible using oxygen.

The oxidative states for common oxidants used in water treatment are shown in Table 3 in relation to the oxidation power of oxygen. Note that all oxidants used in water treatment have higher oxidation potentials than oxygen.

Using ORP to Help Determine Chloramine Degradation

Use of ORP monitoring in a water distribution system, in combination with other water quality parameters, provides a good indication—or snapshot in time—of the stability of the current system. An ORP measurement provides an initial signature of the water system's condition, and ORP values can then be used to determine how fast a condition is deteriorating.

The range of values provided by an ORP can indicate a problem. When ORP is used in combination of the other water quality parameters, it provides a quantitative method for determining if distribution problems can be expected before they occur, giving the operator time to adjust.

Expected ORP Ranges for Chloramination of Finished Water

Figure 6 shows the various ranges of chloramines that can be expected in finished well water and how these values inhibit nitrifying organisms. Chloramine concentrations are shown in ranges, not in numeric values, because the temperature, chemistry, water quality, and pH of each water will differ and thus the ORP is best used for determining acceptable chloramination ranges that result in adequate combined chlorine residual and water system stability.

ORP is thus an indicator of the status of chlroramine degradation at any point in time. Monitoring ORP allows operators to predict the rate of chloramine degradation and take steps to prevent further ORP reductions that will favor nitrification.

The higher values of monochloramine produce elevated ORP values near 500 mV, which can effectively inactivate microbes with longer detention times than are needed with free chlorine. The stability of the oxidation state in a water system will depend on the concentration of pollutants or reducers in the finished water.

When high concentrations of monochloramine are added, bacterial inhibition will occur as long as a highly oxic state exists. If organic material is available, the monochloramine will be destroyed, as shown by the equations in the previous section. Thus, high oxidation states (high mV) are indicative of an environment where nitrification and rapid degradation of chloramine is highly unlikely to occur.

Where oxidation potentials are low or dropping, conditions favor nitrification or nitrification may already be occurring. Thus, these relationships provide a quantitative method for determining the state of the oxidation reactions and the trend toward undesirable low concentrations of disinfectants that are occurring in a water distribution system at any point in time.

Nitrification takes place best in a situation where ammonia is available with elevated temperatures when the pH is between 7.0 and 8.0, but it can occur within a much wider pH range under slower conditions. Decay of chloramine provides a source of ammonia and thus nitrification is fairly common in water distribution systems in Florida that use this disinfectant.

Bacterial Significance in Nitrification

There are two types of ubiquitous bacteria that participate in the nitrification reaction. The first is classified as an aerobic oxidizing bacteria (AOB). In this reaction, ammonia is oxidized to the nitrite form ($NO2^{-}$). Nitrite, as we saw in the chlorine demand example, exerts a chlorine demand of five times its concentration. This situation will result in rapid loss of disinfection residual.

As more ammonia is oxidized, the alka-

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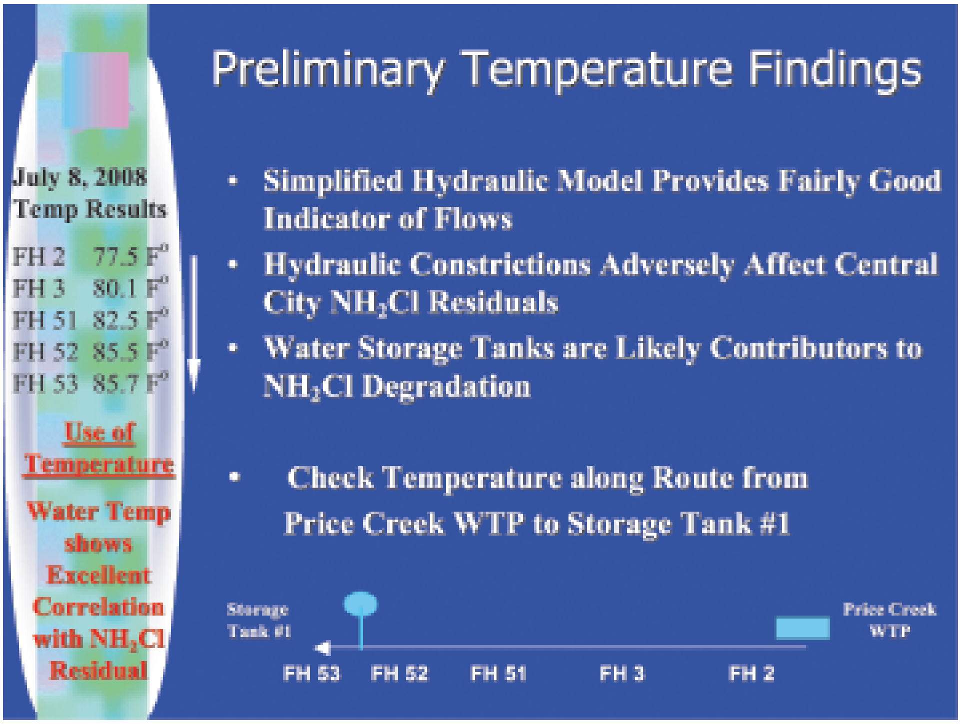
linity in the water is consumed and the pH will drop. A drop in pH is thus an indicator that nitrification is occurring. The conditions for nitrite conversion require a lower oxidation concentration as shown in the figure above. These bacteria are known as nitrogen oxidizing bacteria (NOB).

Lowered oxidation conditions in a water system also promote the growth of biofilm—active bacteria that include both AOB and NOB. These and other bacteria that proliferate under lowered oxidation conditions further complicate the problem in maintaining a chloramine residual in the water distribution system.



Preliminary Temperature Findings

July 8, 2008
Temp Results

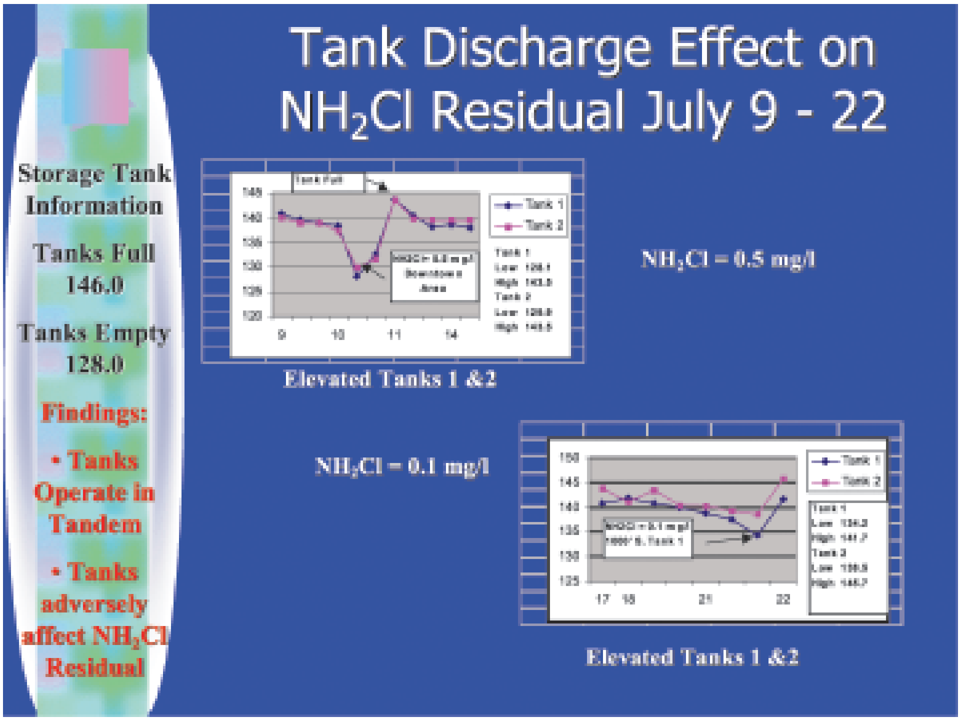
FH 2 77.5 F°
FH 3 80.1 F°
FH 51 82.5 F°
FH 52 85.5 F°
FH 53 85.7 F°

Use of Temperature

Water Temp shows Excellent Correlation with NH_2Cl Residual

- Simplified Hydraulic Model Provides Fairly Good Indicator of Flows
- Hydraulic Constrictions Adversely Affect Central City NH_2Cl Residuals
- Water Storage Tanks are Likely Contributors to NH_2Cl Degradation
- Check Temperature along Route from Price Creek WTP to Storage Tank #1

Figure 7: Lake City, Florida—Chloramination and Nitrification Study, FRWA 2008, Temperature Correlations



Tank Discharge Effect on NH_2Cl Residual July 9 - 22

Storage Tank Information

Tanks Full
146.0

Tanks Empty
128.0

Findings:

- Tanks Operate in Tandem
- Tanks adversely affect NH_2Cl Residual

$NH_2Cl = 0.5$ mg/l

$NH_2Cl = 0.1$ mg/l

Figure 8: Lake City, Florida—Chloramination & Nitrification Study, FRWA 2008, Chloramine/Tank Fluctuation Relationships

Proactive Chloramine Monitoring

Water systems can avoid creating the conditions for nitrification by water system monitoring and taking pre-emptive actions such as flushing or increasing chloramine levels to ensure that adequate oxidative conditions are maintained to prevent bacterial growth.

In monitoring system parameters within the Lake City Water System, temperature was a simple, often-overlooked parameter that provided good chloramine degradation correlation. The temperatures taken along the water's route from the water treatment plant to a water storage tank are shown in Figure 7. It became clear that water temperature was being affected by a local water storage tank that was dominating water volume in the immediate area.

These pipeline temperature readings clearly indicate correlation with storage tank fluctuations. Additional sampling of chloramine concentrations with known tank fluctuations provided the results shown in Figure 8.

The chloramine degradation conditions identified in Figure 8 were easily corrected by plant management by ensuring better cycling in water storage tanks during periods of low peak demand.

Flushing to Increase Chloramine Effectiveness

The most common method of maintaining chloramine residual within a water system at remote locations is to ensure adequate turnover of the water. Unfortunately, a flushing program for a distribution system can be very labor intensive. Manufacturers have developed automated flushing valves for this purpose, as shown in Figure 9.

Flushing can be an effective method for moving fresh chloramine and improving the oxidative state in a water distribution system,

Figure 9: Automatic Flushing Valve
COURTESY KUPFERLE FOUNDRY CO.

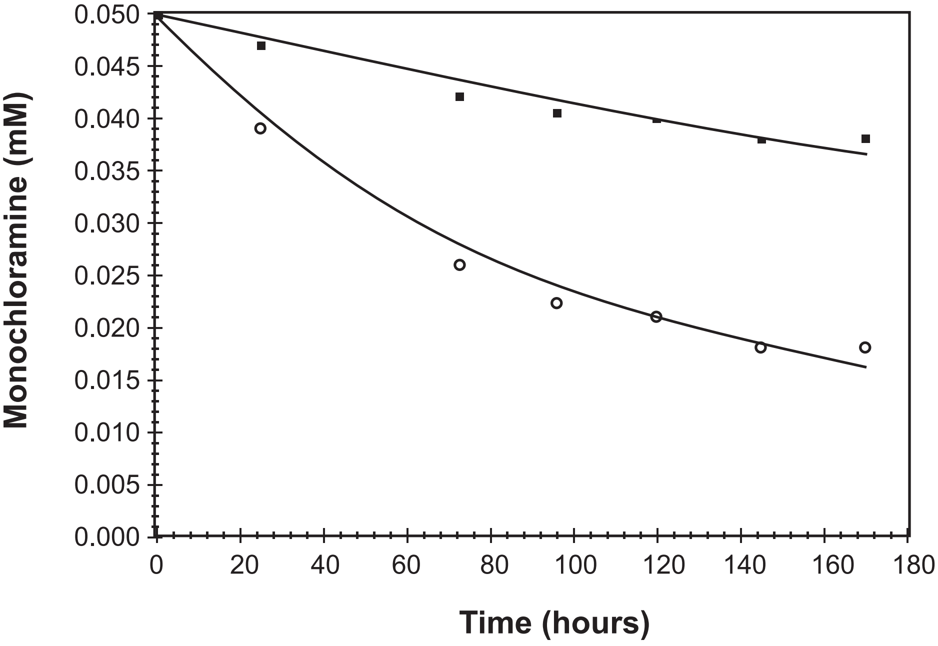


Figure 10: Chloramine Residual Benefits Achieved by Increasing pH in the Water Distribution System

but it should not be attempted without developing a flushing plan that identifies the amount of water needed for flushing and the time the pipe segment needs to be flushed to achieve any degree of success in increasing chloramine residual. Generally a flow velocity of 3 fps is needed to move sediment.

To increase chloramine residual, generally a full pipe volume must be displaced to achieve any benefits. In most cases, the flushing needs only to move water and not sediment. An effective flushing program generally must move only enough water to increase chloramine residual to a target value. Concentration should be confirmed by field testing using a DPD meter and flushing kept to a minimum to avoid wasting water.

Effective Flushing Methods for Achieving Increased Chlorimine Residuals

- Flush three pipe volumes or until the disinfectant residual is restored (usually between 1 and 3 volumes of the stagnant main section).
- Flush until color and turbidity are restored to normal levels (usually 0.5 NTU or less).
- Flush at a rate that keeps the main pressure above 35 psi.
- To minimize water loss, flush for the least amount of time needed.

Methods for Controlling Chloramine Breakdown & Nitrification

Raising chloramine levels to above 2.5 mg/l is the best way to impeded nitrification, but sometimes this is not possible. State drinking water rules prohibit chloramine concentrations in a distribution system from exceeding 4.0 mg/l.

In some cases where distribution systems are several miles long with low demand, a 2.5-mg/l residual can be maintained only by using an additional chloramine dosing facility located closer to the problem area. Attempting to control the concentration at a remote location to above 2.5 mg/l will require a concentration greater than 4.0 mg/l leaving the water plant.

To circumvent the problems with chloramine degradation, using higher chloramine residuals in warmer months is recommended. "Burn outs" (switching to free chlorine for 30 days) may be minimized or eliminated if nitrification conditions are prevented from occurring.

Some systems choose to push the ratios of free chlorine to ammonia to produce some dichloramine to disrupt conditions favoring nitrification in extremely warm weather. Dichloramine will provide a buffer as a more effective disinfectant but can also result in customer complaints of taste and odor; however, its use may preclude a burn out.

Adjusting pH for Maintaining Chloramine Residuals in Water Distribution Systems

Another method used successfully by water systems to maintain chloramine residuals is to maintain an alkaline pH. The limitations here are that very few systems have the ability to adjust pH without adding an additional treatment process. The effects of raising pH are shown in Figure 10.

A pH increase is effective for maintaining chloramine residuals because it slows ammonia release from chloramine degradation.

Use of Blended Phosphates for Chloramine Residual Protection

Some smaller systems have gained similar benefits by using a blended phosphate as a sequestering agent. The blended phosphate works by sequestering both unreacted inorganic metals and any corrosion products produced by bacterial action within the water distribution system. This action is thought to reduce chloramine degradation and chemical activity.

Phosphates, however, must be controlled to minimum dose levels, since they are a nutrient. Typically, dosage is limited by the water hardness and the amount of iron present in the water supply.

When using blended phosphates consideration should be given to its impact on the wastewater treatment system. Batch treatment is not practical because of the initial dose required to build residual and the possibility of corrosion byproduct sloughing off and being flushed into customer plumbing.

Managing Chloramines

It is highly recommended that systems using chloramine establish programs for monitoring total chlorine, ammonia, nitrite, temperature, alkalinity, ORP, and pH—all parameters that can be measured using simple, low-cost field kits. The relationships among various water quality changes on chloramine stability are shown in Table 4.

It is highly recommended that the operator establish signatures in critical areas of the water system and monitor the parameters suggested to observe trends in chloramine breakdown before conditions are allowed to deteriorate. Historical information is most valuable in predicting the likely occurrence of chloramine breakdown, and the pre-emptive measures identified in this article are recommended especially in warmer weather.

References:

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Table 4: Using Chemical Parameters to Determine Effectiveness of Chloramines in a Water Distribution System

#	**Chemical Constituent Change**	**Likely Reason for Drop**
1.	Decrease in Chloramine Residual or residual to below 1 mg/l	Age of chloramine likely exceeds three days and breakdown is occurring
2.	The Oxidation Reduction Potential (ORP) of the water has changed by more than 25 mv to 50 mv. From a previous reading.	Chloramines are degrading
3.	Chloramine Residual is low, can not be maintained and is dropping	Biological growth is occurring and is releasing organic products that increase demand
4.	Ammonia is Present	Chloramine is breaking down and releasing ammonia
5.	Nitrites are present	Nitrification is occurring
6.	pH and alkalinity are dropping	Nitrification is occurring
7.	Higher levels of DBPs are occurring in the Distribution System with no other source water quality changes	Chloramines are breaking down and organic products are being produced
8.	Onset of very hot weather with reduced chloramine residuals	High ambient temperatures > 90° F heating up storage tanks

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