By Pat McCool, KRWA Consultant

Monochloramine: Free Chlorine Reacting with Ammonia

One of the most important duties that operators perform is achieving and maintaining adequate chlorine residuals. Adequate residuals are necessary to ensure that adequate disinfection occurs at the source treatment plant or well and that KDHE regulatory requirements for chlorine in the distribution system are met. This is especially challenging for systems having monochloramine residual.

Many water supply systems operate with monochloramine residual in their distribution systems and storage tanks. The monochloramine residual is formed when free chlorine combines with ammonia that is added to the water or is natural in the groundwater.

Ammonia is added at almost all Kansas surface water treatment plants to limit the amount of disinfection byproducts (DBPs) formed when free chlorine reacts in the water. Also, ammonia is sometimes added by systems that purchase water and add additional chlorine for monochloramine residual.

Monochloramine formation

When chlorine (gas chlorine, sodium hypochlorite, calcium hypochlorite) is added to water (H2O) it forms hypochlorous acid (HOCl) and hypochlorite ion (OCl-) in the water. Hypochlorous acid and hypochlorite ion together are known as free chlorine. The free chlorine will react with natural ammonia in the water and / or react with ammonia added to the water to form monochloramine. The free chlorine and ammonia must be in proper portions to each other to form monochloramine,

If the free chlorine and ammonia are not in proper portions to each other, then resultant residual problems may occur. The proper portions are 4.2 mg/l of free chlorine will react with 1.0 mg/l of ammonia calculated as ammonia; or 5.1 mg/l of free chlorine, which will react with 1.0 mg/l of ammonia measured or calculated as ammonia nitrogen.

Most ammonia feed system calculations use 4.2 as the purchased ammonia in the powder or in the solution is listed in a % of ammonia of the chemical purchased. Sometimes, the 5.2 is used as the free ammonia test kits give the resulting free ammonia measurement in the water as ammonia nitrogen, that is, the nitrogen in the ammonia.

Restated simply, 4.2 mg of free chlorine will react with 1.0 mg/l ammonia. Free chlorine is measured as Cl2 and ammonia is measured as ammonia.

The aforementioned difference between ammonia as ammonia and ammonia as nitrogen is because a molecule of ammonia (NH3) is 82% nitrogen. Molecular weight of ammonia = 17; molecular weight of nitrogen = 14, and molecular weight of hydrogen = 1; 14/17 = 0.82.

The correct portions are in the chemistry of the reaction of free chlorine and ammonia to form monochloramine. If the portions are not correct, then residual loss MAY occur.

Residual loss in reaction

Free chlorine and monochloramine can react with each other to form dichloamine. In forming dichloramine both free chlorine and monochloramine are destroyed. As a result, if there is too much free chlorine in the reaction, monochloramine residual will be destroyed.

In general at a treatment plant where ammonia is added, the monochloramine residual downstream of the ammonia addition point should numerically equal the free chlorine residual immediately upstream of the ammonia addition point. For example, 2.4 mg/l of free chlorine residual upstream of the ammonia addition point should give 2.4 mg/l

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monochloramine downstream of the ammonia addition point.

One fundamental rule and corollary on which monochloramine residual hinges is: If too much free chlorine reacts with ammonia, the resultant residual will decrease. If there is not enough ammonia to react with the free chlorine, the resultant residual will decrease.

Again, if there is too much free chlorine in the water to react with the ammonia in the water, the resultant residual will decrease and be lower.

If there is too much ammonia in the water to react with the free chlorine, the resultant monochloramine residual will not decrease and will not be different numerically than the free residual in the reaction. There will be then some excess "free", unreacted ammonia in the water.

Again, if there is too much free chlorine in the water to react with the ammonia in the water, the resultant residual will decrease and be lower.

Troubleshooting problems

The most common operational problem in regard to water treatment that this author receives phone calls about is the loss of monochloramine residual at a treatment plant or in the distribution system. With regard to a treatment plant, the loss of chlorine residual is the predominant problem, and the loss is most likely caused by the chlorine addition and ammonia addition being added in the wrong proportions and / or reacting in the wrong portions.

Although the chemistry of reactions is known, chemical feeding equipment problems, efficient mixing in the water at the point of application of each chemical, proper solution strengths, testing methods, location of monitoring locations for free chlorine and resultant monochloramine are somewhat different from place to place. These differences can cause problems in the control and monitoring of the successful monochloramine formation.

In reviewing plant operations and chemical addition and monitoring, one tactic that is considered and often used is to double the ammonia dosage for a short period of time and monitor the downstream resultant monochloramine residual. This often gives substantial information on the cause of residual loss and helps quantify what the chlorine and ammonia feed rates should be to give the operator's desired residuals in the treatment plant.

Doubling the ammonia dosage for a short period of time does not adversely affect the water quality. Typically and most often ammonia is added to around 1.0 mg/l. Some Kansas groundwater supplies have natural ammonia levels around 2 to 3 mg/l, so doubling is not a water quality problem.

Technical assistance

If you have questions about chlorine residual at your treatment plant or in the distribution system or any other water supply issue, you can contact the KRWA office at 785-336-3760 or email to krwa@krwa.net or contact me at 785-215-9427, pat@krwa.net. KRWA has the experience and resources to help with any water or wastewater utility issues.

Pat McCool has worked as a consultant to KRWA since January 2004. He previously worked for KDHE for 30 years. Pat has a bachelor's degree in Chemical Engineering and a master's degree in Environmental Engineering from the University of Kansas.