Medora Corporation

Fast Response, Early Boost: Eliminate Ammonia Oxidizing Bacteria

Potable water storage tanks in chloraminated systems endure water quality problems, particularly during warm weather. A simple approach can solve these problems, enhance a facility’s mixing system, and save money.

Historically, attempts to solve water quality problems in chloraminated systems that use water storage tanks have been minimally successful. Many storage tank facility managers have reported problems of nitrite formation and rapid loss of residual disinfectant. But experiments conducted during 2006 and 2007 in more than 50 tanks at two California locations indicate that nitrite formation and loss of residual disinfectant can be minimized or eliminated with a fast response and early chlorine boost. The solution offers numerous benefits and eliminates some complexity in complying with the Stage 2 Disinfection Byproduct rule. A fast response–early boost plan consists of implementing an aggressive water quality monitoring plan for warm weather conditions, as well as establishing trigger points in tanks that signal situations requiring a boost in chlorine levels.

THE PROBLEM

The primary source of trouble in many chloraminated potable water storage tanks is ammonia- oxidizing bacteria (AOB). Chloraminated water generally has five sources of free ammonia that feed AOB:

- Some free ammonia remains in the water when chloramines are manufactured at the treatment plant.
- Free ammonia can remain after the chlorine component of chloramines has been depleted in killing bacteria
- Free ammonia can be released from bacterial bodies after they are killed by chlorine.
- Free ammonia can form from the auto-decomposition of chloramines into chlorine and ammonia, which occurs readily when existing free ammonia is consumed by AOB or when water age exceeds five days.
- Free ammonia can form when mono- chloramine converts to di-chloramine.
- This process occurs rapidly when the chlorine-to-ammonia ratio exceeds 5:1 in a particular portion of a tank.

Trouble arises when AOB converts free ammonia to nitrite and then to nitrate. Although both are harmful to human health, the nitrite level is usually the first to cause a compliance violation by exceeding the 1.0-mg/L limit. Warm water aggravates the situation because the bacteria growth rate generally doubles for every 10°c rise in water temperature. In addition, AOB are about 13 times more resistant to chloramines than to chlorine. Therefore, the combination of free ammonia, warm weather, and chloramine resistance creates a perfect environment for disinfectant loss and nitrite violations.

Studies indicate that when chloraminated water reaches 15°c (59°F), AOB start growing rapidly. In the process, these AOB consume nearly all of the free ammonia in the tank, causing, in turn, an acceleration of chloramines, by auto- decomposition, into chlorine and more free ammonia. As the AOB continue to consume free ammonia, a positive feed- back loop results, and most of the residual chloramine in the tank can be destroyed in just a few days following the onset of nitrite formation.

To kill the AOB, a mixer must quickly and thoroughly circulate the chlorine boost throughout the entire tank.

THE SOLUTION

Addressing these problems is a two-step process: managers must be able to spot the problem and then boost chlorine levels. Both of these steps rely on an adequate mixing system.

Rapid Response. Interrupting the rapid formation of nitrite and corresponding chloramine loss as soon as possible is essential. Twice-weekly water testing is recommended when tank water temperatures reach 15°c or higher. This comprehensive testing should be conducted on representative water samples and include total chlorine, free chlorine, ammonia, nitrite, nitrate, pH, and dissolved oxygen.

A well-mixed tank is essential to conducting good testing. In well-mixed tanks, one or two water samples—from anywhere in the tank—are sufficient for proper testing. For example, if a tank's temperature variance at several locations, from top to bottom in the water column, is from 0.1°c to 0.5°c, the tank is mostly de-stratified, and two water samples will probably be representative of water in the entire tank. Tanks with a 24-hr/day active mixing system will probably be well mixed if the system has a long-distance flow pattern and operates at a flow rate high enough to pump the entire tank volume through the mixer every two days. However, if a tank isn't well mixed, it's virtually impossible to obtain representative water quality samples on which proper management decisions can be based.

Boost the Chlorine. During the twice-weekly water testing, watch for trends— even changes as small as 0.1 mg/l are important if a trend is becoming apparent. If chloramine residual levels and free ammonia are declining, or nitrite levels are rising, give the tank a small chlorine boost immediately.

Each utility should establish its own trigger point for chlorine boosting. Depending on tank size, an immediate chlorine boost of just a few pounds of chlorine can return the tank to good water quality in minimal time. For example, to boost 1 mil gal of water by 0.5 mg/l of chlorine requires only 3.3 gal of 12.5 percent sodium hypochlorite. If boosting isn't implemented at the first sign of trouble, water quality can spiral downward rapidly and require a tank to be taken offline, deep-cycled, or taken through breakpoint chlorination.

Chemistry. In a warming tank, the first sign of trouble is often a decline in the level of total chlorine. This drop occurs because the chlorine is depleted in killing bacteria, which proliferate in warmer water.

At the same time and as a result of chlorine loss, free ammonia increases and then plummets as soon as AOB start converting it to nitrite. A chain reaction is set into motion, with more free ammonia forming and then quickly being converted to nitrite. In just a few days, chlorine and free ammonia levels may approach zero while nitrite levels continue to spike. At this point, the tank may need to be taken offline for breakpoint chlorination **(See figure on page 3)**.

When the chlorine boost is mixed into the tank water it forms hypochlorous acid, which doesn't immediately combine with free ammonia to form new chloramines. This reaction takes several hours because of chemical and physical impediments. In the meantime, an effective mixer will put the hypochlorous acid to work at destroying bacteria, including AOB, throughout the entire tank.

It's important to note that hypochlorous acid is a "hotter" disinfectant than chloramines, and AOB have far less resistance to hypochlorous acid than to chloramines. Therefore, the hypochlorous acid from the chlorine boost kills AOB fairly rapidly. Over a period of hours, some of the remaining hypochlorous acid from the boost will combine with free ammonia to form chloramines, thus pushing the system back to the desired operating point.

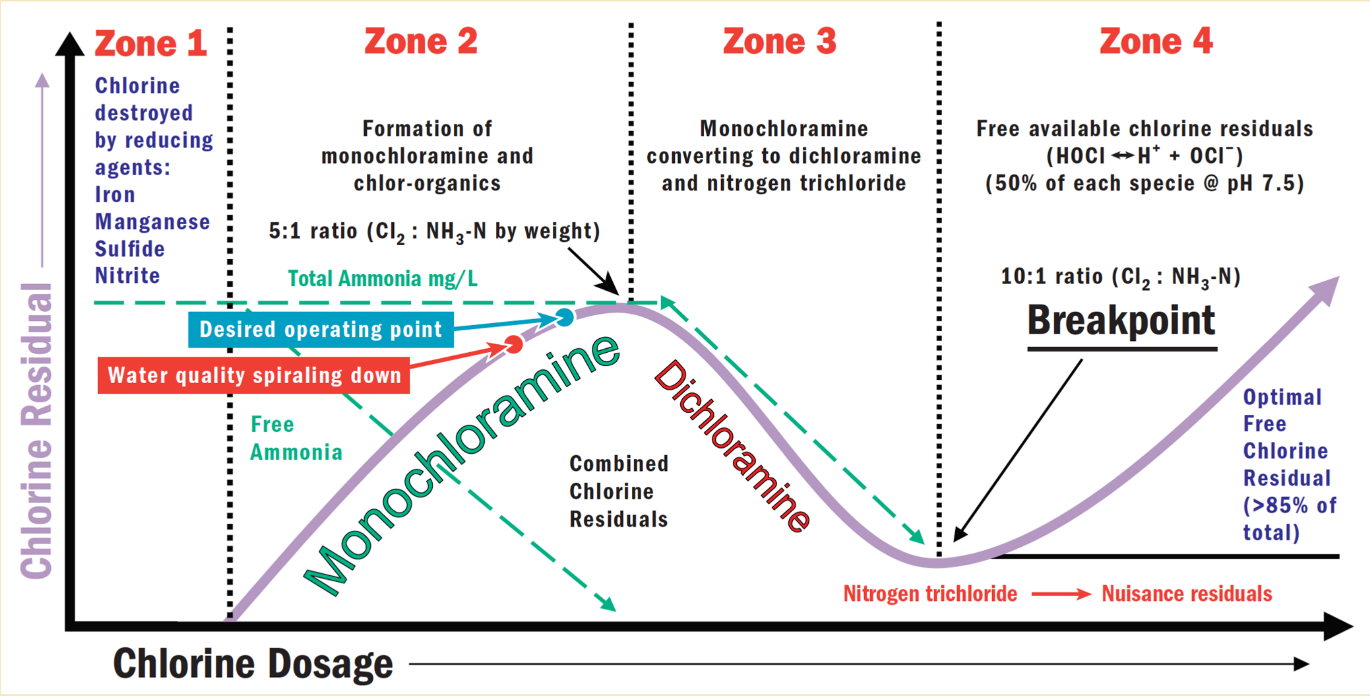
It's important to have a good mixing system in place to implement boosting, because to kill the AOB the mixer must quickly and thoroughly circulate the chlorine boost throughout the entire tank, all the way to the bottom sediment layer, sidewalls, and all other boundary layers. In short, the chlorine boost will be only as effective as the tank's mixing system.

SOLVE PROBLEMS, SAVE MONEY

Fast response and an early chlorine boost effectively prevent nitrite formation and loss of residual disinfectant in chloraminated tanks in warm weather. It can also help to ensure compliance with the Stage 2 Disinfection Byproduct rule. When implemented properly, this method can help managers maintain water quality and avert recurring problems that are costly in terms of lost water and time consumed by management and field crews.

Breakpoint Chlorination Curve Interpretation*

Comparing total and free chlorine, total ammonia-N, and free ammonia will help you determine your location on the breakpoint curve.



***Zone 1:** Initial chlorine demand is caused by reducing agents (Fe^{+2}, Mn^{+2}, H_2S, NO_2^-) that consume most of the chlorine applied prior to forming combined residuals.

Zone 2: Additional chlorine combines with available total ammonia and reactive organics until forming maximum monochloramine residual. At the same time, uncombined free ammonia is being depleted until it reaches zero.

Zone 3: More chlorine dosage converts monochloramine into odorous dichloramine and nitrogen trichloride. Total combined chloramine residual decreases and ammonia concentration approaches zero at the breakpoint.

Zone 4: True free chlorine residual is obtained and provides the least nuisance odor when free residuals make up 85 percent of the total chlorine concentration. Nuisance combined chlorine residuals survive and the potential for disinfection by-products (trihalomethane and haloacetic acid) formation remains, as free chlorine residual develops further.

Source: Spon, R. (2008, June) Do you really have a free chlorine residual?. Opflow, pp. 24-27.

About Medora Corporation

GridBee® and SolarBee® brand equipment provide solutions for difficult problems across the water quality spectrum including lakes, drinking water, and stormwater applications. Please contact us to discuss how we can help you make water better.