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Andrew Seidel is chief executive officer of UGSI (www.UGSIcorp.com), Poway, Calif.

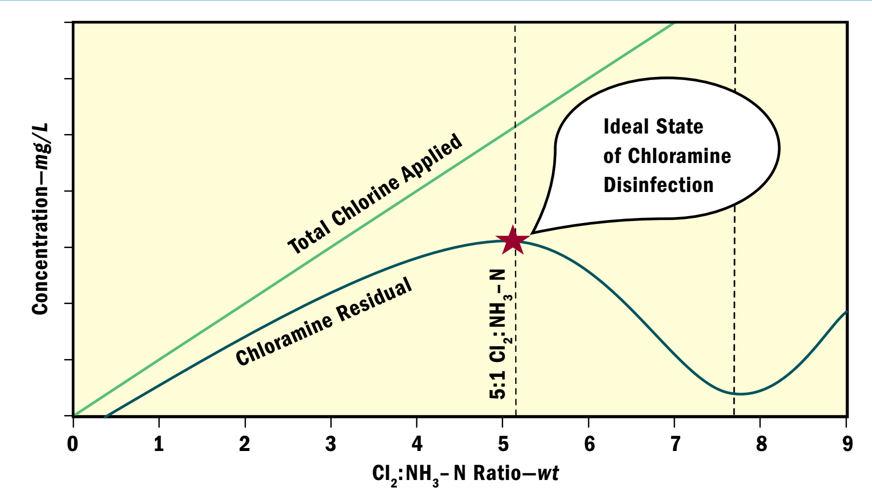
Utility Finds Way to Manage a Tank's Chloramine Residual

The East Bay Municipal Utility District (Calif.) successfully used a mobile on-site sodium hypochlorite generator, coupled with dosing logic and tank mixing, to achieve adequate tank chloramine residuals during a time of drought, which led to the technique's adoption. **BY ANDREW SEIDEL**

LOCATED ON THE eastern side of San Francisco Bay, the East Bay Municipal Utility District (EBMUD) treats and distributes water to more than 1.3 million customers in Alameda and Contra Costa counties. EBMUD chloraminates water before distribution and uses chloramines for secondary disinfection to mitigate disinfection by-product (DBP) formation during distribution. Chloramine, formed by reacting aqueous chlorine with ammonia, is less prone to react with organic precursors in the distribution system and therefore doesn't promote DBP formation. However, maintaining disinfectant residual set points can be challenging for many utilities because of the complexities of chloramine chemistry in distribution systems.

Figure 1. Chlorine Breakpoint Curve

A chlorine breakpoint curve illustrates the monochloramine peak.



CHLORAMINE CHEMISTRY

When chlorine as sodium hypochlorite or as gas is added to water, the chlorine and water react, and the key product is the strong disinfectant hypochlorous acid (HOCl).

(Gas Chlorine) $Cl_2 + H_2O \rightarrow HOCl + HCl$

(Sodium Hypochlorite) $NaOCl + H_2O \rightarrow HOCl + NaOH$

If ammonia (NH_3) is present in the water from introduced source water or intentional dosing, HOCl reacts with NH_3 in a series of chloramine reactions that can create desirable and undesirable products, such as monochloramine (NH_2Cl), dichloramine ($NHCl_2$), or trichloramine (NCl_3) in extreme cases:

- $NH_3 + HOCl \rightarrow NH_2Cl$ (monochloramine) + H_2O (when ratio of Cl_2:NH_3 is ~3–5:1)
- $NH_3 + 2HOCl \rightarrow NHCl_2$ (dichloramine) + $2H_2O$ (when ratio of Cl_2:NH_3 is ~5–7:1)
- $NH_3 + 3HOCl \rightarrow NCl_3$ (trichloramine) + $3H_2O$ (when ratio of Cl_2:NH_3 is significantly higher than ~7:1)

Of these chloramine products, only monochloramine is an effective disinfectant, with dichloramine and trichloramine creating taste and odor problems.

An EBMUD cross-functional water quality team explored new ideas for managing chloramine residual levels, ultimately deciding on a packaged trailer system for on-site sodium hypochlorite generation. Shown here, from left, are EBMUD's Boyce LeGrande, David Beyer, Steve Kachur, and Charmin Baaqee.

The US Environmental Protection Agency and AWWA recommend a Cl_2:NH_3 ratio of 3–5 to 1 for drinking water disinfection, as detailed in AWWA Manual 56, *Nitrification Prevention and Control in Drinking Water*.

Although monochloramine is one of the longest-lasting water disinfectants, it does decompose over time and generates free ammonia in the process. Chloraminated water decomposition accelerates when water temperatures exceed 60° F and ammonia is liberated. Ammonia-oxidizing bacteria (AOB) feed on the free ammonia, which converts into nitrites (maximum contaminant level 1 mg/L) and nitrates (maximum contaminant level 10 mg/L).

"The formation of nitrite isn't really a problem from an MCL standpoint," explains Susan Teefy, EBMUD's manager of regulatory planning and analysis. "Even if 100 percent of the added ammonia were converted to nitrite, the concentration would be well below the nitrite MCL. The concern is the loss of chlorine residual and subsequent increase in microbial counts."

Once established, the AOB colonies continue to rob the system of disinfectant capacity, potentially resulting in a tank having to be taken off line for "breakpoint chlorination" (see Figure 1) to neutralize AOB colonies, or, in extreme cases, dumped to reestablish the disinfectant residual from scratch. Flushing or dumping a water tank in drought-stricken California is an increasingly unacceptable outcome for utilities.

A SPRAWLING DISTRIBUTION SYSTEM

As with many large utilities, EBMUD manages an expansive distribution system. The system formed in 1923 and evolved organically over the years, with operators making the most of existing assets to efficiently serve communities across a varied geography. EBMUD's service area extends more than 330 $mi.^2$ along the eastern shore of San Francisco Bay. The wide geographic spread and hilly topography have resulted in a water distribution system organized into more than 150 pressure zones served by five treatment plants and 170 water storage tanks and reservoirs.

Having converted to chloramines in 1998, EBMUD operators developed a toolkit to optimize residual management in their sprawling system and combat nitrification. Tank cycling and mixing, as well as boosting disinfectant levels, are techniques used to ensure water quality, especially as warmer temperatures during the summer create demand changes and adversely affect water quality.

"Everyone is looking for the silver bullet to control nitrification," says Steve Kachur, EBMUD's water distribution superintendent. "It doesn't exist. Nitrification is a chronic problem that we need to constantly manage with both new and old approaches."

THE CASE OF TICE RESERVOIR

Despite a deep understanding of its system, along with the inherent challenges of chloramine management, EBMUD, like all utilities, deals with its own set of "problem children." Located in a lower-pressure zone and with limited opportunity for cycling

A chloramine residual management trailer allows EBMUD to more easily deploy the sodium hypochlorite generation and tank mixing system (inset) to trouble spots.

because of low local demand, the 10-mil gal Tice Reservoir (40 ft high × 200 ft wide) couldn't maintain an adequate disinfectant residual, notwithstanding a consistent high-quality source water.

In spring 2014, an EBMUD cross-functional team of operators and water quality experts surveyed the market and interviewed companies with new ideas for managing chloramine residual levels. They knew a solution had to involve simultaneously controlling three parameters: (1) adding adequate mixing energy to a tank to create homogeneous conditions, (2) creating favorable conditions for mixing chlorine and ammonia, and (3) managing the chemical dosing ratio to fit the changing tank conditions. Additionally, the team preferred a packaged trailer system, as mobility might allow the equipment to be deployed to other trouble spots.

On-Site Sodium Hypochlorite Generation With Tank Mixing. In summer 2014, EBMUD deployed a trailer unit for a four-month trial period at Tice Reservoir. The trailer included an on-site sodium hypochlorite generator that provided up to 40 lb/day of chlorine equivalent at approximately 0.8 percent concentration; a liquid ammonium sulfate (LAS) skid; a chemical analyzer package with dosing control logic; and a 150-gpm tank mixer, which was placed inside the reservoir.

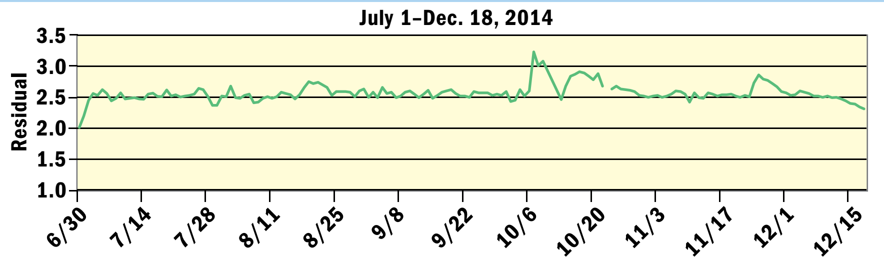
By using LAS and 0.8 percent sodium hypochlorite to generate monochloramine, the trailer was easily serviced and maintained. Consumables included salt and electricity to generate the sodium hypochlorite and the LAS, which was provided as a 40 percent (10 percent NH_3) solution in 5-gal pails.

Additionally, the service and safety requirements were reduced by using on-site generated hypochlorite versus 150-lb chlorine gas cylinders or commercial hypochlorite (12–15 percent concentration). The water booster pump and chemical metering pumps were located inside the trailer, with the process tubing (hypochlorite, ammonia, and water) running up the wall of the reservoir and into the in-tank eductor-type mixer.

Diver- and Outage-Free Mixer Installation. Mixer installation was accomplished without divers or a service outage because the mixing unit was installed through the reservoir hatch and has no moving parts or electrical components in the tank itself. EBMUD provided 480 voltage alternating current, three-phase power out of the tank vault, and a 4-in. water tap from the same vault. Using the trailer option also simplified EBMUD's permitting process, resulting in a faster deployment during the critical warm summer months.

Figure 2. Tice Reservoir Residual Readings

Continual residual readings throughout six months were taken from the Tice Reservoir chloramine residual management system.



SUCCESS LEADS TO WIDER USE

Once the unit was engaged, chloramine residual set points were achieved and maintained in less than 48 hr. For the next six months, EBMUD monitored the Tice Reservoir system's performance and never experienced degraded water quality or had to take the tank out of service (Figure 2). Salt and LAS consumption were related to tank demand and turnover. On average for the time period, the system used 5–10 bags of salt per month (for hypochlorite generation) and 5–15 gal of LAS. The process and Tice Reservoir project were so successful EBMUD decided to implement additional units in other problematic parts of its service area to help manage chloramine residuals and prevent nitrification events.