Residual Maintenance in a Distribution System

Long detention times cause problems for Nebraska water system.

By Gene Schroeder

The Cedar Knox Rural Water Project (RWP), in Northern Cedar and Knox counties, NE, needed to reduce the formation of total trihalomethanes (TTHMs) while maintaining a chlorine residual at the farthest reaches of the distribution system. The water project serves four communities and 721 hookups with a total of 3,200 customers in Northeast Nebraska. The source for drinking water is the Lewis and Clark Lake, fed by the Missouri and Niobrara rivers. Average winter flow is 300,000 gpd with flows peaking at 750,000 gpd in the summer.

Cedar Knox traditionally treated the water with 150-lb chlorine gas cylinders, utilizing a maximum of about 25 lb per day of chlorine. In the past, operators had to load the chlorine gas into their trucks and transport it to the water plant since the chlorine delivery truck could not access the plant. The disinfectant is injected prior to the clearwell and has about six to eight hours of detention time before going out to distribution. The distribution system covers 360 miles of pipelines with the longest reach being 43 miles from the treatment plant. The water frequently has a six- to seven-week detention time in winter with an additional three to four weeks of detention in Obert, NE, which is the farthest customer from the plant.

With use of gas chlorine, the Cedar Knox RWP would have occasional TTHM excursions over the previous limit of 100 ppb. With the reduced limit of 80 ppb impending, the utility needed an effective and immediate solution to TTHMs in the distribution system. In addition, the typical gas chlorine dosage to maintain a point of entry reading of around three mg/L was not sufficient to sustain the old requirement for a 0.02 mg/L residual at the longest residence point. Cedar Knox would occasionally approach EPA's maximum chlorine dosage of four mg/L in an attempt to maintain the required residual at the end of the line, to no avail. As the chlorine dose increased, TTHMs would further increase, adding to the already existing problem.

MIOX-252 system at Cedar Knox Rural Water Project.

Cedar Knox began investigating solutions. Personnel read about on-site mixed-oxidant technology in an industry journal, and discussed on-site generation with colleagues in a neighboring state also considering a conversion from chlorine gas. The water project decided to purchase the on-site mixed-oxidant equipment in June 2000. The system operates using salt, water, and power, converting a brine solution into chlorine-based mixed oxidants via two electrolytic cells, each with a 25-lb per day capacity. Each cell has its own dedicated power supply, brine pump, and control panel, providing complete operational redundancy to meet daily chlorine requirements.

After first installing the system, even though levels of iron and manganese in the water were low, the utility experienced more maintenance than expected due to iron and manganese fouling of the cells. The electrolytic cells had to be acid-washed every two to three weeks (every 163 to 220 hours of operation) and the system brine filters changed out every four to five weeks. Operators were spending half an hour weekly on maintenance of their new system versus half an hour every six months on the previous chlorine gas system. On the recommendation of the manufacturer, the utility now adds one bag of "Red Out" citric acid for every ten bags of salt, resulting in much less contamination. Maintenance has improved measurably, with the cells only having to be acid-washed every eight to ten months (1,200 hours of operation) while filter

MIOX electrolytic cell.

replacement is only required every 12 months. Maintenance requirements have dropped to less than one half hour per month.

Cost Analysis

The utility was able to make these changes for an installation cost of about $75,000. Salt and electric cost for the mixed-oxidant equipment is running at 3.4 cents per 1,000 gal of water treated, with maintenance costs of $450 per year. The total flow last year was 130,346,000 gal, equating to a total annual cost of operations of $4,882 ([130,346,000 gal x $0.034 ÷ 1,000 gallons] + $450 = $4,882).

The estimated operations cost for gas chlorine is slightly higher at 3.9 cents per 1,000 gal of water treated, with estimated maintenance costs of $50 per year. The total annual cost with chlorine gas would have been $5,133 ([130,346,000 gal x $0.039 ÷ 1,000 gal] + $50 = $5,133). With on-site generation, the utility is saving about $250 per year.

More importantly, the water project has significantly reduced TTHMs and is now in compliance with the new required 0.2 mg/L chlorine residual at all points in distribution. After running the on-site mixed-oxidant pilot system for one month, TTHMs measured 50.2 ppb, the lowest measurement since 1993. A temporary conversion back to chlorine resulted in an immediate increase in TTHMs, up to 108 ppb. Since permanent installation and operation of the equipment in August 2000, TTHMs have been consistently 30 percent to 50 percent less than when using chlorine gas, with current values around 74.5 ppb.

To bring the utility comfortably into compliance with the 80 ppb limit, carbon treatment is being added before clarification, which will reduce disinfection by-product precursors, further reducing formation of TTHMs in the treated water. Pilot test trials with powdered activated carbon gave evidence of another 30 percent reduction in TTHMs beyond what mixed oxidants alone were able to accomplish, bringing Cedar Knox comfortably within the limit at 50 to 55 ppb.

After several months of operation with mixed oxidants, Cedar Knox also discovered that the chlorine residual was now lasting to the farthest reaches of the distribution system. In fact, the utility was able to reduce the chlorine dose by 30 percent to 50 percent. With a residual of only 1.8 to 2 mg/L leaving the plant, in contrast to the previous dose of 3 to 3.6 mg/L, a stable and durable chlorine residual of about 0.4 mg/L is maintained at all points in distribution. This residual lasts six to seven weeks to the farthest point in distribution, and lasts an additional three to four weeks of detention in Obert's distribution system. Being able to utilize a lower dose also helps the utility with TTHM formation since there is less chlorine to react with organic material in the water. The utility attributes the longer-lasting residual to the mixed-oxidant disinfectant removing biofilm in distribution pipelines, thus enabling the chlorine to endure without being consumed by the oxidant demand of biogrowth.

In summary, Cedar Knox has dramatically reduced TTHM formation with use of on-site generated mixed oxidants, while maintaining a much more durable chlorine residual that lasts to the farthest reaches of distribution, through a total period of 11 weeks, both within Cedar Knox's and Obert's water supply. Had the maximum 4 mg/L residual leaving the plant been implemented to meet the residual requirements at the end of the line, TTHMs would likely be double the current levels, so the benefits of disinfection by-product reduction go beyond what can be quantified. These gains have been accomplished without the use of chloramines or chlorine booster stations. In addition, plant personnel no longer have to transport chlorine gas cylinders to the plant. I have no doubt that the system would not be operating as effectively as it is without the use of mixed oxidants. GE

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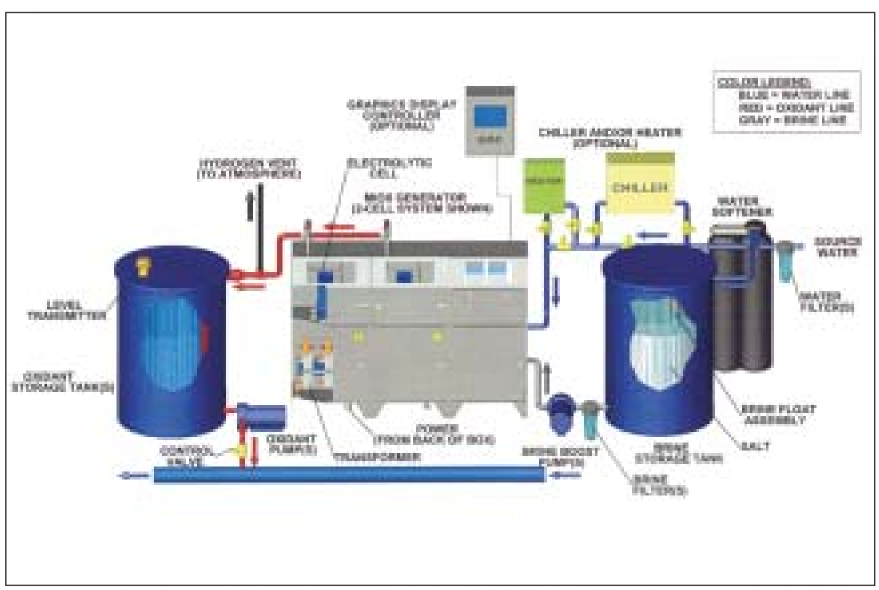

On-site generation process flow diagram.