by Pat McCool

Rechlorination of combined chlorine water: a case study

One of the major responsibilities of operators is to maintain the required chlorine residuals in the distribution system. The Kansas Department of Health & Environment (KDHE) requirement is to maintain a minimum of 1.0 mg/ combined chlorine residual or 0.2 mg/l of free chlorine residual throughout and at the far ends of the distribution system. Chlorine residuals will vary and so operators usually try to maintain residuals higher than the required minimums.

Chlorine residuals are important, as the presence of chlorine is an important indicator that contamination has not occurred and the water is safe to drink. All water supply systems are required to take at least one daily chlorine residual in the distribution system. These residuals should be taken at different locations rotating throughout the system to ensure that all parts of the distribution system have adequate chlorine residuals.

Pat McCool
Consultant

Many consecutive water supply systems do not chlorinate the water (that is, rechlorinate). They are totally dependent on the water supplier for chlorine residuals. Many of these systems cannot maintain residuals in their distribution system, especially with the warmer water temperatures in the summer.

Consecutive systems purchasing from a water supplier using a surface water source have more difficulty maintaining chlorine residuals in that the water warms up more than water from wells in the summer time. Also, if the water supplier is using combined chlorine residual, maintaining chlorine residuals in the summer is more difficult than if a free residual is being used. Dealing with warmer surface water and combined chlorine is the challenge of many consecutive systems. The city of Hartford in Lyon County is an example.

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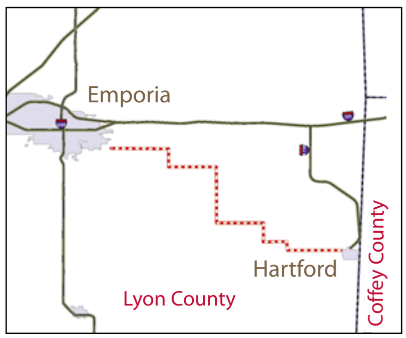

The situation and problem defined

The city of Hartford purchases water from the city of Emporia. Hartford has a clearwell measuring 36 ft. by 24 ft. and pumping station on the southeast edge of Emporia. Water from Emporia enters a concrete, underground clearwell from which the water is pumped approximately 15.5 miles to Hartford.

The Hartford pumping station is a substantial block structure that is located at the southeast edge of Emporia.

The 6-inch PVC transmission line from the pumping station to Hartford holds approximately 120,000 gallons. Thus, the water takes about 2.5 to 4 days in the winter and about 1.5 to 2.5 days in the summer to reach Hartford.

There are three sampling locations for chlorine residual on the transmission line. One is located 1.5 mi. east of the station, one about halfway to Hartford, and the other as the line enters Hartford.

The sodium hypochlorite solution tank and pump at left and sodium hypochlorite mixing and dilution system above are located in the pump station. Liquid sodium hypochlorite was chosen over gas chlorination because the pumping station was not constructed with a separate room for the safe storage of the chlorine gas cylinders.

In the fall of 2005 it was determined that the combined chlorine residuals were below the 1.0 mg/l requirement. Also, the northeast area of town showed no chlorine in the water. The northeast area is farthest away from where the water enters town and is sparsely populated.

Also, many years ago the city was supplied by a well. The water entered the city from the northeast. This area is suspected to have much more corrosion deposit in the old, cast iron lines. These deposits are great sites for bacterial growths.

The chlorine residuals leaving the pumping station were not high enough to maintain a 1.0 mg/l residual where the water enters Hartford. The city operators flushed water extensively in the hope of increasing the chlorine residual entering town. This did not succeed.

The operators and a city contractor then pigged the 15.5-mile water transmission line from Emporia to Hartford to remove any deposits or bacterial growths that the line might have in the hope of increasing the chlorine residuals entering town. This also did not succeed.

Thus, on October 11, 2005 it was determined rechlorination at the pumping station would be necessary to increase the residuals for both the rural customers along the transmission and the city customers.

When the water temperature began to decrease, the residuals in the transmission began to increase and then the residuals in town began to increase. With continued, extensive flushing the city was able to maintain low residuals for the winter and spring months before the water temperature increased.

In the late Spring 2006, the city began rechlorinating the water at the booster station. From knowledge gained in the subsequent summer and winter, the city also began adding ammonia to the water in late May 2007. The operating experiences and data have given some important lessons in rechlorinating water with combined chlorine residual.

Above: *Free ammonia levels in the water entering the pumping station are measured with the free ammonia and monochloramine tester.*

Right: *The ammonium sulfate solution tank and diaphragm pump at right adds the solution to the water entering the pumping station clearwell.*

Lessons learned

The loss of combined chlorine residual from the Emporia water treatment plant in northwest Emporia to the Hartford pumping station in southeast Emporia was much greater during the warmer water temperature months. However, from mid-December through mid-April there does not appear to be much loss at all.

The residual loss is caused by the growth of nitrifying bacteria in water; the bacteria are likely attached to the surfaces of the storage tank and distribution piping. The residual entering the Hartford pumping station is around 3.0 mg/l in the colder months and around 1.0 – 1.4 mg/l in the summer months. This loss of combined residual was also seen in the transmission line from the pumping to the city of Hartford. Without rechlorination, the residual entering Hartford goes to zero during the warmer times.

Chlorination, actually rechlorination, with liquid sodium hypochlorite, was chosen over gas chlorination because the pumping station was not constructed with a separate room for the safe storage of the chlorine gas cylinders.

Control of the rechlorination level was very difficult with the first diaphragm pump purchased. Adjusting the chlorine level with the speed/frequency knob and/or stroke-length knob proved unworkable. This may have been cause by a faulty pump. However, the dosage was controlled by adjusting the strength of the fed solution by diluting the 10% solution with water. This method requires good mathematical calculation but proved quite workable in this situation.

The calculated chlorine residual from rechlorination is always somewhat greater than the measured residual at the pumping station tap. This may be due to any of the following three reasons.

First, sodium hypochlorite solutions are known to lose strength with time. Thus, the sodium hypochlorite strength may be less than 10%. Secondly, once the hypochlorite is injected there may not be good mixing to provide an efficient reaction. Thirdly, there may not be sufficient reaction time before the sampling location tap to give an accurate reading.

Even with good monitoring and adjustments to the chlorine feed rate, it was difficult to maintain a constant, desired level of combined chlorine residual leaving the pumping station. Also, to maintain required combined chlorine levels in Hartford, higher residuals were needed leaving the pumping station. Both these problems were solved by the addition of ammonia to the water in late May last year.

Free ammonia is the ammonia in the water that is not combined with chlorine. Free ammonia levels in the water entering the pumping station were measured with a colormetric test kit. The free ammonia level was found to vary sometimes significantly on a day-to-day basis. Also, the free ammonia level was not high enough to rechlorinate the water sufficiently to achieve the desired levels of combined chlorine entering Hartford.

The system's ammonium sulfate weighing process consists of cups, a surface to catch any spillage, a kitchen portion scale, pencil and paper.

An ammonium sulfate solution was made by adding six to 12 ounces of dry ammonia sulfate per gallon of water. This solution was added in the water entering the pumping station clearwell. This solution was pumped with a diaphragm pump. The amount of ammonia fed is determined by the desired increase in the residual from rechlorination.

It was decided to add the ammonia to the water entering the pump station clearwell; that is, the ammonia was added before rechlorination. Whenever possible, it is important in rechlorination to add the ammonia before the chlorine is added. Otherwise, the chlorine added might be in excess of the free ammonia available to react with in the momentary time before ammonia is added. In that case, the resultant chlorine residual may in fact be lower than the overall residual from what would be expected with that level of chlorine added.

Since beginning the addition of ammonia to the water, the combined chlorine residuals have been raised enough to maintain required chlorine residuals in Hartford. Also, the ability to maintain constant, desired chlorine residuals has been significantly easier. Most likely, ammonia addition is needed where rechlorination is practiced; especially if the residuals that are needed/desired are higher than the residuals leaving the supplier's water treatment plant. This is the case in the Emporia/Hartford situation.

Rechlorination of combined chlorine residual is a difficult/complex process. The chemical reactions must be understood. Equipment and feed rates must be correct. The process must be monitored daily and adjusted if necessary. Operators who understand this know that it is not "merely adding chlorine to the water."

On a daily basis, the Hartford operators monitor processes and mix the chlorine and ammonia solutions. This is needed to ensure required residuals are maintained in town.

As a side note, the city has recently obtained a grant and loan to replace the cast iron lines installed in town in 1930. This will significantly reduce the residual loss in town from the rust deposits in the old cast iron lines. However, rechlorination will still be needed but probably on a more limited basis; that is, lower residuals leaving the pumping station and fewer months of the year.

The 2008 KRWA conference has a day-long pre-conference session on the topic of maintaining chlorine residuals. I encourage systems to attend it and the numerous additional sessions offered.