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Teamwork in Progress

Lowering DBPs in Combined Systems

by Jan C. Routt

Maintaining good disinfection and overall quality water while lowering disinfection by-product (DBP) levels has been the main focus of a more than five-year team effort between Owenton Water in Owenton, Ky., and Kentucky American Water's TriVillage System. Prior to this partnership, the relatively small (less than 10,000 population) combined system had been experiencing unusually high levels of trihalomethane (THM) chlorination by-products.

Owenton Water is a city-owned utility that operates a reservoir-supplied conventional 1-mgd treatment plant. The facility provides drinking water to the city of Owenton and surrounding areas. Owenton's source water — an algae-rich impoundment supplemented by a "backwater" river tributary — had been suspected as a key factor in DBP formation. About half of the water produced by the Owenton facility is sold to TriVillage, a privately owned Kentucky American Water system. The combined systems serve much of Owen County and portions of Grant and Gallatin counties in north-central Kentucky.

Both systems were applying chlorine in routine treatment and distribution operations to provide disinfectant residuals throughout distribution, but how the source water quality, plant treatment, and distribution operations contributed to DBP formation was not clearly understood. By 1999, when TriVillage approached KAW to purchase TriVillage, the state

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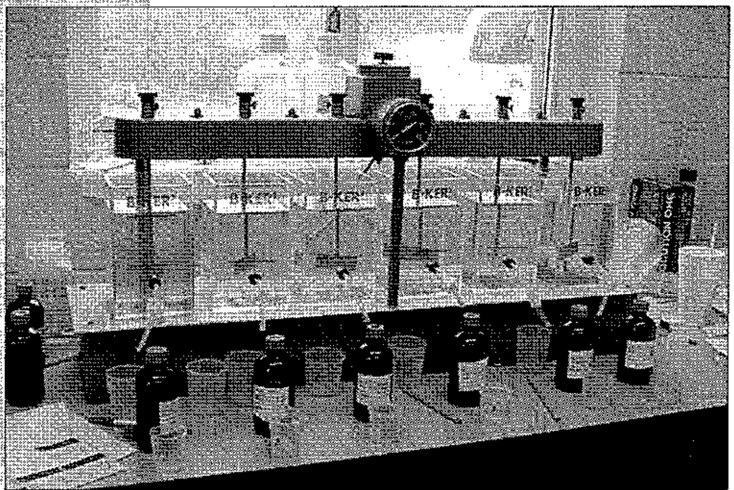

Numerous jar tests were conducted to predict and verify effective dosages with new treatment schemes.

had been requiring for several years that the TriVillage and Owenton systems conduct THM monitoring and regularly issue health-based public notices for elevated THMs. KAW agreed to help solve the DBP issue, with the final purchase agreement contingent on resolving the DBP problems.

Consumers and officials in these systems wanted immediate improvements; however, because major changes to the plant or the source water would require significant funding and state approval, a thorough look at all factors involved, from the source water through treatment and the distribution systems, was needed. Successful planning and implementation of the necessary studies and process changes has required ongoing communication and cooperation among the utilities and state and local officials. Short-term improvements were needed while longer-term fixes were being identified and implemented.

Immediate Changes for Short-Term Benefits

Jan Routt is the director of water quality for Kentucky American Water in Lexington, Ky. She has a Kentucky Class IV Water Treatment Plant Operator Certification and a BS degree in Microbiology from the University of Kentucky.

Data collected early on by KAW, in cooperation with TriVillage and Owenton, helped define the factors responsible for the high levels of DBPs and provided insights for operational improvements that could be made to decrease DBPs in the short term. Sampling data also clearly showed that converting to better source water would be key to improving water quality in the long term. The nearby Kentucky River, located a few miles from the plant across challenging terrain, was identified as the best new source. But, switching source waters, which involved designing and building new intake and transmission facilities, was understood to be a long-term project.

To lower DBPs before the completion of a new Kentucky River intake and transmission line, operational changes were needed. Any treatment changes also had to be consistent with current and developing state and federal regulations and guidance. Profiles were developed of total organic carbon (TOC) removal and THM formation, as well as disinfection through the plant and distribution system, to determine the best treatment and distribution operation options using the existing sources and treatment facilities.

Process profiles revealed that natural organic matter was being poorly removed and high levels of DBPs (THMs and haloacetic acids [HAAs]) were being formed in the treatment plant. And, DBP levels increased even more with rechlorination and travel time through the distribution system. In some instances, excessive retention time fostered disproportionate DBP increases, which were observed in the distribution system; these were addressed mainly by ensuring a good turnover (minimizing water age) in distribution storage tanks. Treatment changes consisted of optimizing chlorine disinfectant application and maximizing natural organic DBP precursor removal in a phased process over several months. State approvals were granted during each step. Results of each step were assessed before proceeding to the next phase.

Step One: Enhancing Coagulation

Source studies revealed Owenton's reservoir source water to have fairly high alkalinity (140 mg/L) and variable to moderately high TOC. The average TOC level has been 4.7 mg/L, but the source water TOC was 5.4 mg/L when the actual conversion was made to enhanced coagulation, and levels as high as 12 mg/L have been measured in the Severn Creek supplementary source. Prior to these changes, plant TOC removal, using alum–lime coagulation with pH 7.8, was a less-than-desired 28 percent. This TOC removal efficiency would not meet the Stage 1 Disinfectants/Disinfection By-products Rule removal requirement (which was pending at the time) and left appreciable TOC in the finished water to react with chlorine, forming DBPs in the plant and during distribution storage and transmission.

Jar studies showed that relatively simple changes in coagulation treatment would improve TOC removal. The first changes consisted of ceasing pre-lime application and increasing (approximately doubling) the alum dose to lower treated pH to 6.9. Relying solely on inorganic coagulant for pH suppression in a moderately high-alkalinity water was not the best long-term choice, but it would enable short-term improvement while plans for the new intake and source water were being developed.

The change in coagulation chemicals required the addition of postfiltration caustic feed (50 percent sodium hydroxide) to adjust finished water pH to about 7.6–7.8 for continued distribution system corrosion control. Detailed operations procedures were developed, and operator training was provided, to ensure safe use of caustic soda.

The "good news" was that these operational changes went quite smoothly. The "not-so-good news" was that coagulation and corrosion treatment changes roughly doubled the chemical costs for the Owenton facility and increased the operator time needed to regularly drain additional solids from the plant's one solid-contact upflow clarifier. The filter backwash and clarifier solids-handling system also had to be modified to process additional solids. This was accomplished by adding polymer to the backwash water to improve settling and increasing the frequency of solids removal from the backwash settling tanks. After conversion to the new intake and the river source water and plant modifications are considered, the solids-related operational costs and constraints will be further assessed.

Even more good news was that these coagulation enhancement measures roughly doubled TOC removal, bringing the treatment process comfortably into compliance with TOC removal requirements. And, chlorine residuals were persisting longer in the system, allowing lower rechlorination doses at master metering points. THMs were decreased by only 15 percent, however, so the next step was to further evaluate plant disinfection and seek state approval to move the point of chlorination to later in the treatment process. And, to minimize excess solids levels and improve

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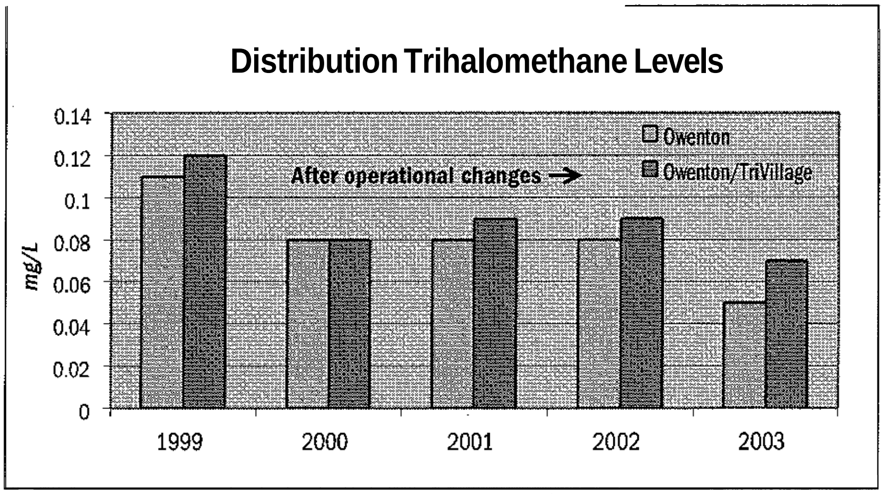

Operational changes resulted in a dramatic reduction in trihalomethane levels in **the Owenton** system and a significant reduction in THMs for the combined systems.

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settling characteristics in the plant's single upflow clarifier, bench studies were done to support a change from alum to ferric chloride coagulant.

Step Two: Convert to Top-of-Filter Chlorination

Prior to step-two changes, the plant was thoroughly assessed for adequate disinfection contact time. Tracer studies were conducted in the well-baffled plant clearwell, and operations guidelines were changed to raise the minimum operational level of the clearwell to offset disinfection contact time that would be lost in precoagulation on conversion to prefilter chlorination. The state was petitioned to allow conversion from rapid-mix (precoagulation) chlorine application to top-of-filter (intermediate) chlorine application. In addition, new procedures were developed, and operator training was provided, to ensure proper optimization of the pretreatment potassium permanganate feed, because $KMnO_4$ would be the only oxidant applied prior to clarification after conversion to intermediate chlorination.

The state approved the changes to ferric chloride coagulant and intermediate chlorine application to be conducted in sequence and under dose supervision in May 2000. Detailed jar studies were performed before and during the coagulant switchover to support a successful change from alum to ferric chloride. The conversion to intermediate chlorination was approved with the contingency that substantial additional testing would be conducted before the switch — and each month thereafter — to verify good disinfection. This supplementary testing included monitoring of source-related water quality parameters, such as TOC and organic nitrogen, along with added microbiological sampling (heterotrophic and total coliform bacteria) through treatment and the distribution system.

Through these efforts, the plant was successfully converted to ferric chloride and intermediate chlorination in May 2000. Filtered water quality was maintained, and changes have brought THM levels well-below the new limit of 0.08 mg/L, which took effect for systems serving less than 10,000 people in January 2004. Testing has also shown that HAAs were greatly reduced (by more than half) when prefilter chlorination was replaced with intermediate chlorination. Monitoring of HAAs and THMs in the distribution system has begun this year for regulatory compliance purposes. Levels will be tracked closely to verify that the current short-term operational scheme is enabling compliance with the new and lower limits as they take effect.

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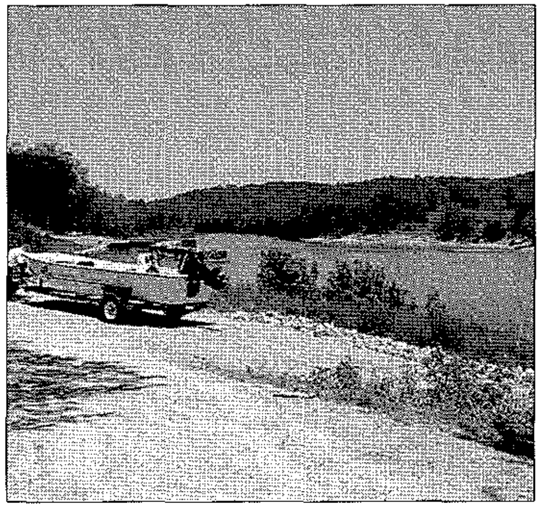

Comparison testing of the proposed Kentucky River intake site and the Severn Creek tributary required instream sampling.

Source Manganese a Challenge

During June and July 2001, the second summer after enhancing coagulation, an incidence of lake turnover raised dissolved manganese to levels that were not treatable with potassium permanganate alone. This caused a brief episode of discolored water, forcing a *temporary* return to minimal *pre-chlorine,* and, ultimately, a short conversion to yet another coagulant, polyaluminum chloride.

The polyaluminum chloride coagulated successfully at a higher pH (8.0), while enabling manganese removal with permanganate. By late July, the reservoir manganese subsided and the treated pH was lowered again, with a return to ferric chloride. Fortunately, the phenomenon of. lake turnover causing high dissolved manganese and discolored water has not reoccurred since the summer of 2001.

Distribution System Optimization

Along with the plant treatment changes for Owenton, TriVillage has given extra attention to optimization of booster chlorine feed at its two master meters. Changing the treatment at Owenton to improve TOC removal allowed a reduction in the booster chlorine needed to maintain residuals throughout the TriVillage distribution system. Both systems have worked to ensure good water turnover in the distribution systems. Some additional distribution flushing was needed to remove briefly occurring discolored water just after the initial change to post-caustic for distribution corrosion control. Since the changes, both systems have met lead and copper action levels and total coliform limits in their respective distribution systems.

Both Owenton and TriVillage have cleaned and inspected their distribution storage tanks in the same time frame as the plant treatment and booster chlorine optimization. This undoubtedly helped overall water quality by removing any residual sediments that had collected in the tanks. Extra testing for DBPs and chlorine and heterotrophic plate counts routinely verify continued water quality throughout the system.

Long-term Plans

All the hard work to reduce TOC and optimize chlorine application and system flows has paid off in lowered DBPs and better preparation for the new D/DBP regulations. Testing for study purposes supports that the changes made to improve THM levels have also lowered HAAs. Levels of both will be tracked closely through this first compliance year.

Additional interim steps to control these DBPs will be implemented if needed. However, progress on the new Owenton intake and transmission line from the higher quality — and quantity — Kentucky River source will be essential for best long-term success. This new source water promises to enable further lowering of DBPs as regulations become more stringent in coming years and as the service area grows.

Work to relocate Owenton's intake in the Kentucky River has been supported through these cooperative activities and extensive ongoing testing. Intake and transmission line design has been completed and regulatory approvals are in progress. Funding has been sought and procured, with projects expected to be complete in the coming year.

Sample Location	Thomas Lake*	Severn Creek*	River Pool No. 2**
TOC (*mg/L*)	6.57	6.05	2.58
DOC (*mg/L*)	6.05	5.94	2.50
UV-254	0.126	0.140	0.046
SUVA	2.07	2.24	1.84
Ammonia (*mg/L*)	0.014	0.012	0.008
Organic Nitrogen (*mg/L*)	1.1	1.4	0.3
Phosphate (*mg/L*)	0.21	0.41	0.25
Alkalinity (*mg/L*)	131	135	60
Total Coliform (*cfu/100 mL*)	335	940	10
Fecal Coliform (*cfu/100 mL*)	181	733	4
Fecal Strep (*cfu/100 mL*)	782	1504	5
HPC (*cfu/100 mL*)	121	162	90
Giardia/100 L	42.55	49.5	89.39
Cryptosporidium/100 L	< 42.55	< 49.5	< 42.9

** Existing Owenton source waters*
*** Proposed New Intake Site, Kentucky River Pool No. 2*

Table 1. Source Water Quality Comparison Table

Lessons Learned

With multiple regulatory and governmental agencies and water systems involved, as well as the media and public, good ongoing communication and cooperation have been essential. This included frequent presentations and discussions with up-to-date technical information presented in formats meaningful to all involved.

Sampling and testing of source waters, along with treatment plant and distribution system profiles, were useful in defining the factors contributing to DBP formation. Supplementary sampling and testing have been helpful to verify and ensure that the total water quality balance is maintained — such as microbial disinfection, turbidity removal, and corrosion control — both before and after the changes.

The ongoing water quality action plan and consequent results have been essential to support system growth and service to unserved areas for these systems. For example, a small private system was annexed into the TriVillage system in 2001, allowing the decommissioning of an ailing small treatment facility and source that would have required a significant capital upgrade to meet new regulations. Additional projects extending water service to adjacent unserved areas have been approved and recently completed. These system consolidations and extensions might not have been considered possible without clear evidence that both Owenton and KAW TriVillage were on track to comply with increasingly stringent water quality regulations.

Water quality improvements have been realized with short-term operational changes, while long-term capital changes are being planned, funded, approved, and constructed. Customers have noticed the changes, particularly improved water clarity and taste, and they now have a higher confidence level overall in water quality. With a team working together, persistently and cooperatively, complex water quality problems such as DBPs in small systems can be tackled and resolved both now and in the future.

A shorter version of this article first appeared in What's on Tap, the newsletter for the KY/TN Section AWWA.