Responding to a New Year's Day Water Treatment Crisis for a Surface Water

Joseph Downey

Decatur Utilities in Decatur, Ala., owns and operates a potable water treatment facility that uses the Tennessee River as its sole source of raw water. The utility produces an average of 28 mil gal per day (mgd) to serve approximately 30,000 customers in all portions of the city of Decatur, and routinely provides water to the city of Hartselle, Northeast Morgan County Water District, and Limestone County. The town of Trinity and West Morgan East Lawrence Water District have the capability to buy water from Decatur Utilities upon request.

The water treatment plant (WTP) has the permitted capacity to treat 68 mgd of raw water. Chemical treatment consists of using sodium permanganate for oxidation, fluoride to promote dental health, polyaluminum chloride for coagulation, lime for pH adjustment, polyorthophosphate for stabilization, and chlorine for disinfection. There are four in-ground water storage tanks and six elevated storage tanks that provide a combined capacity of approximately 24 mil gal of water.

Treatment Status Preceding the Event

The WTP had been operated as a traditional treatment facility since the 1930s. Traditional treatment included raw water chlorination, coagulation, sedimentation, filtration, prelime, postlime, and chlorine disinfection. In 2009, the utility committed to upgrading chemical processes in order to reduce disinfection byproducts (DBPs). Because the primary concern in Decatur was trihalomethanes (THMs), chemical treatment upgrades included the following strategies:

- Reduce or eliminate raw water chlorination
- Use permanganate as raw water oxidant
- Reduce or eliminate lime feed to keep pH low
- Use an alternate coagulant to aluminum sulfate (alum) that will work well without prechlorination and prelime
- Incorporate postphosphate to allow the depressed finished water pH

The utility conducted full-scale pilot testing of sodium permanganate as the primary raw water oxidant and polyaluminum chloride (PACl) as the coagulant in October 2009, and made the switch from alum to PACl in March 2010. The change to PACl, along with the use of sodium permanganate, was directly related to anticipating compliance with the Alabama Department of Environmental Management/U.S. Environmental Protection Agency (ADEM/EPA) Disinfection Byproducts (DBP) Stage 2 Rule, which became effective Jan. 1, 2012. The pilot testing of PACl, in conjunction with sodium permanganate, lowered DBP levels on average by 50 percent on finished water leaving the WTP and 10 to 40 percent across the distribution system, as compared to DBP values using alum and chlorine.

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Description of Event

On Jan. 2, 2011, following a rain storm of approximately 4.8 in. over two days, the WTP recorded elevated raw water turbidities as high as 68 nephelometric turbidity units (ntu). Raw water temperature also significantly dropped due to extremely cold-air temperature during the same period. The WTP was feeding PACl in the range of 30-40 mg/L at the beginning and during the first few hours of the increased raw water turbidity event. At approximately 9 p.m., the WTP lost its filtering capabilities in all 40 filters due to high-filtered turbidities (>0.3 ntu) and high settled water turbidities (>16.0 ntu). At this point, the WTP ceased pumping finished potable water into its distribution system due to high-filter turbidities above 0.30 ntu in order to avoid violating its ADEM water supply permit.

The utility also evaluated the option of pumping noncompliant potable water into the distribution system, but strongly believed this option was a last resort, as it would have caused considerable issues for the water system's customers. This option would have also created an

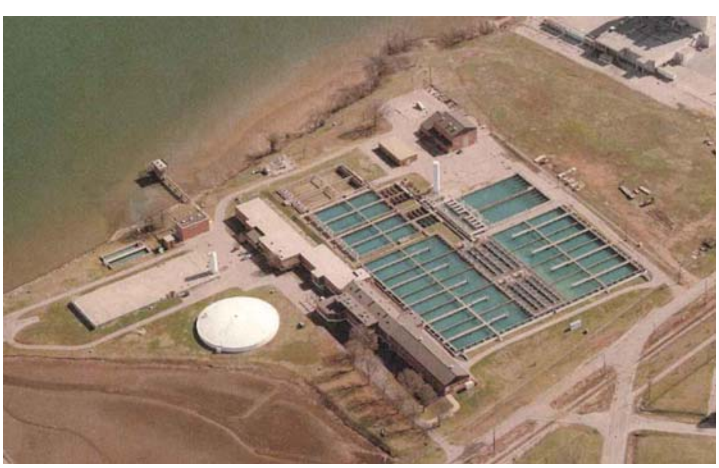

Figure 1. Decatur Utilities Water Treatment Plant

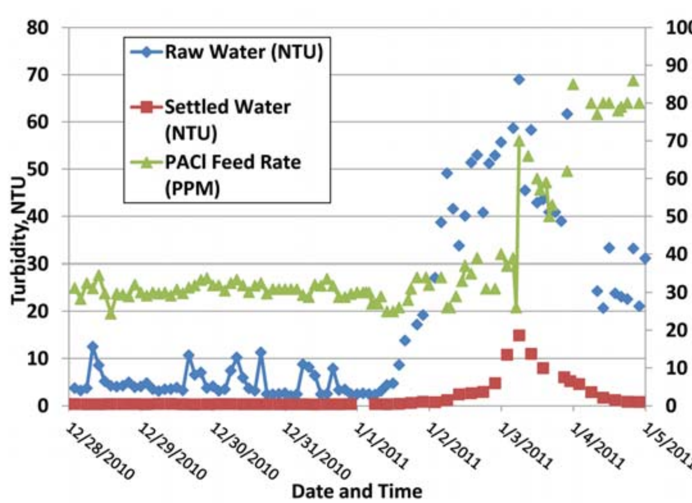

Figure 2. Water Characteristics During Crisis Event

additional burden on the distribution system, pumping stations, and water storage tanks due to the need to flush the entire system with compliant potable water. The utility eventually resolved the treatment problem during the night of January 3 by increasing the coagulant (PACl) dosage rate to a feed range of 85 to 105 mg/L. The utility resumed water distribution on the morning of January 4, which required approximately 12 hours to refill the water storage tanks before system pressure was restored.

Figure 2 shows the raw and settled water characteristics during the event. It was noted that the utility experienced a similar raw water event in December 2010, just one month prior to the January 2011 event, but that winter storm did not affect treatability. Therefore, the following questions were developed to try to understand why the first winter storm did not affect treatability, yet the second event greatly affected treatability:

- Did the two storms wash out different watersheds?
- Was there a difference in water quality chemistry?
- Did the water temperature cause problems?
- Was there a difference in total organic carbon (TOC) between the storm flows?
- Were there differences in particle-size distribution or particle surface chemistry between the storm flows?
- Is PACl the right coagulant?
- Did raw water chlorination and permanganate help or hurt?

After-Event Response

Immediately following the crisis event, the board of directors for the utility commissioned a comprehensive study to review the cause of the treatability problems and to also determine if the management staff properly communicated during the crisis. The study included the following components:

- Review raw water data and plant data
- Review operator records and treatment tests during the crisis
- Perform bench-scale treatability tests to simulate the raw water conditions during the crisis and evaluate chemical treatment strategies
- Develop treatment protocols for similar future events
- Develop management protocols to communicate and make decisions during similar future crisis events

The comprehensive study was started in March 2011 and completed by July 2011 using research tasks performed by Constantine Engineering, HDR Engineering, and Auburn University. Based on the findings and recommendations from the comprehensive study, the utility developed specific treatment protocols that have been implemented to avert future crises. Although similar water quality issues have occurred in the winters of 2012 through 2015, the standard operating procedures (SOPs) for treatment have allowed the WTP to continuously produce excellent finished water quality.

Comprehensive Treatability Study

The most significant effort during the treatability study was to perform extensive simulation research in a laboratory, attempting to simulate the raw water conditions during the treatment crisis and assess various factors that affected treatability, as well as strategies to improve treatability. This research was completed at Auburn University, with the following objectives:

- Analyze the river water
- Test turbidity removal with 23 sediment/soil samples
- Explore the natural organic matter (NOM) effect on turbidity removal
- Examine influence of temperature on turbidity removal
- Test combined influences of NOM and temperature
- Examine influence of iron and manganese on turbidity removal
- Probe effects of chlorine and sodium permanganate ($NaMnO_4$)
- Test turbidity removal at different dosages
- Compare performance of alternate coagulants

The raw water simulation was constructed by simply collecting various sediment samples in the watershed immediately adjacent to the WTP intake, then extracting NOM/TOC, as well as inorganic characteristics, that represented the Tennessee River water quality. The "synthetic" raw water samples were then adjusted for factors that included temperature, pH, iron/manganese content, and NOM/TOC content. All treatability tests during the research were conducted using standard jar testing apparatus, with mixing and settling characteristics that simulated the WTP characteristics. Hundreds of laboratory trials were completed, which revealed very valuable information as follows:

- This evaluation assumed that the best simulated fit to represent the peak effluent turbidity during the January incident was achieved using native NOM at 6.14 mg/L and temperature at 7°C.
- Turbidity removal by PACl is significantly impacted by the amount of NOM.
- Lower temperature slows coagulation reactions, but is not as significant as other factors.
- The impact of iron and manganese on turbidity removal using PACl is negligible.
- The impact of pH and alkalinity on turbidity removal using PACl is negligible.
- Increasing PACl dosage as necessary should be the first action during future similar shock loading.

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- Addition of chlorine and permanganate will further enhance the removal and should lower the coagulant demand.
- PACl outperformed the other two conventional coagulants, alum and ferric chloride (FeCl), for turbidity removal and TOC removal in the simulated water.
- TOC and color can serve as "early warning" parameters in raw water.
- Frequent TOC and color monitoring is highly recommended.

Figures 3 through 7 demonstrate a few of the significant trial results.

Water Treatment Plant Standard Operating Procedure Changes

Following the results of the treatability study, the utility implemented the following goals and changes to the management protocol and SOPs at the WTP:

- Equipment was added to provide on-line monitoring of raw water TOC, preflocculant chlorine (Cl) and manganese (Mn) residuals, and finished water THMs.
- Operators are conducting regular jar tests and will increase the frequency of testing as raw water quality changes. All tests and operating decisions are now documented.
- An emergency response plan was developed to establish better protocol for communication among WTP operators, the WTP superintendent, and management during significant variations in plant performance, as well as emergency situations such as equipment failures.
- Water quality parameters were developed to identify "early warning" signs to help operators anticipate water quality changes that will require plant chemical changes.

In the four years since implementing these changes, the WTP has experienced at least four significant events in which raw water quality rapidly changed with regard to turbidity, temperature, and TOC. With the new SOPs in place, operators easily managed chemical feed decisions and were able to successfully produce high-quality treated water throughout these potentially critical events.

Furthermore, the utility has been successful at achieving the original objective of changing water treatment chemicals and treatment strategy: reduce DBPs through existing treatment technology without the need for expensive alternate technology to achieve compliance with Stage 2 DBP requirements. Distribution system DBPs have consistently remained 20 to 40 per-

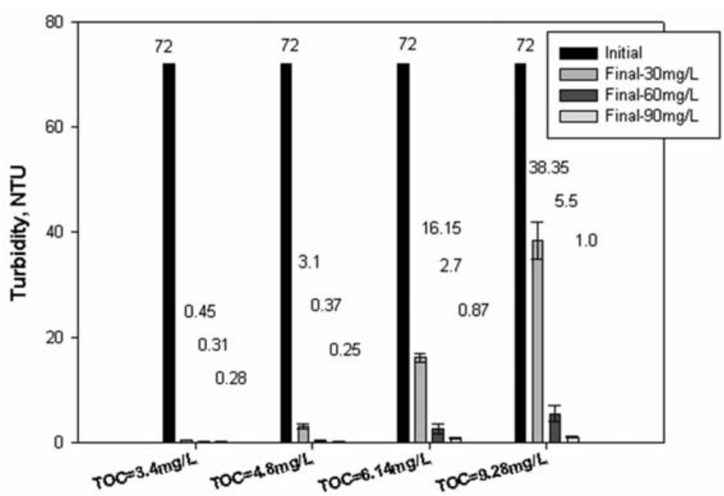

Figure 3. Effects of Low Temperature and Increasing Natural Organic Matter on Turbidity Removal

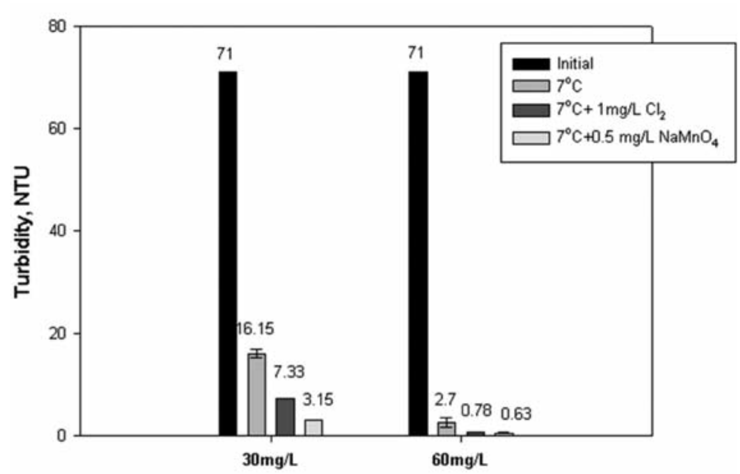

Figure 4. Low Temperature Turbidity Removal with Addition of Chlorine (Cl) and Manganese (Mn)

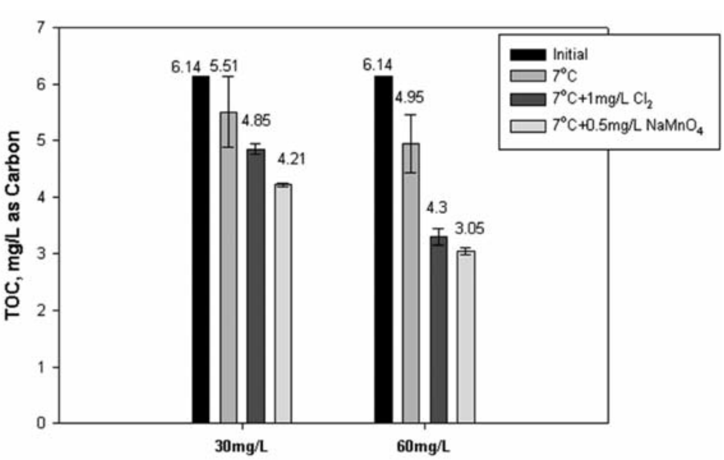

Figure 5. Low Temperature Total Organic Carbon Removal with Addition of Chlorine (Cl) and Manganese (Mn)

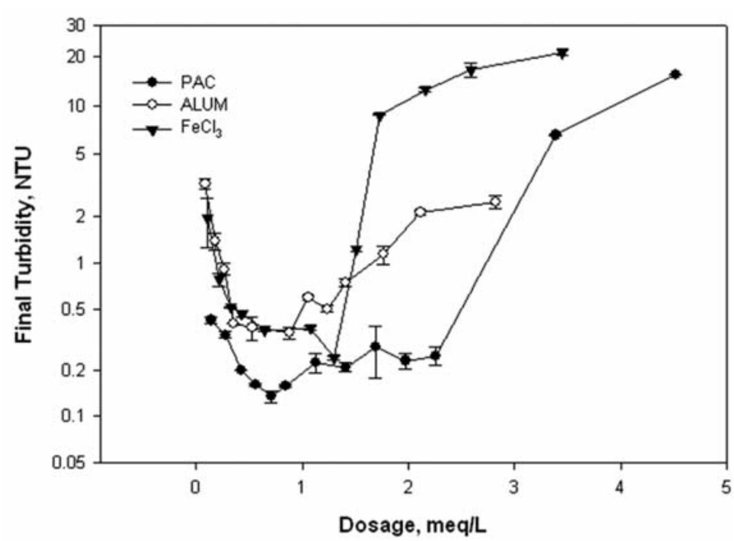

Figure 6. Turbidity Removal With Alternate Coagulants

cent lower than previous results using alum as a traditional coagulant. Wholesale water customers are also able to meet their own DBP requirements because of lower TOC in the Decatur water.

Summary and Conclusions

Understanding raw water quality and the related chemistry effects can greatly assist WTP operators during routine days, as well as on critical days. The utility used the bad experience of a crisis to better understand raw water characteristics, improve treatability, develop better SOPs, and develop an emergency response plan.

For the Tennessee River raw water, the utility has determined the following useful treatment strategies:

- PACl appears to outperform other coagulant options with regard to turbidity removal, TOC/NOM removal, and DBP control.
- TOC/DOM greatly affects coagulant dosage requirements for turbidity removal.
- Water temperature slows the chemical reaction, but is not a significant factor.
- Prechlorine and permanganate can assist PACl in the removal of turbidity and TOC.
- Using PACl as the coagulant, followed by finished water conditioning with polyphosphate, has provided successful compliance with Stage 2 DBP requirements.

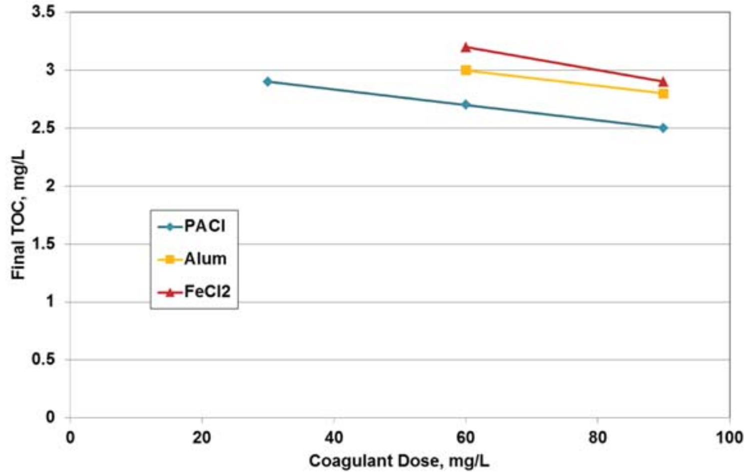

Figure 7. Total Organic Carbon Removal With Alternate Coagulants

Acknowledgements

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