Chlorine Dioxide Treatment for Disinfection Byproduct Reduction

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One of the largest issues facing Florida utilities today is the reduction of disinfection byproducts (DBPs) to comply with the Stage 2 Disinfection Byproducts Rule. Current treatment methods of DBP precursor reduction, such as membrane treatment, ion exchange, and granular activated carbon treatment, can incur significant capital and operational expenses. Many utilities have turned to chloramine disinfection to minimize DBP formation, which offers minimal capital expense, but chloramine disinfection brings its own routine challenges to maintaining distribution systems.

Background

Initial Considerations

Today, the most commonly used disinfectants for potable water are chlorine and chloramine. The use of chlorine is increasingly subject to criticism due to its numerous disadvantages and hazards. Chlorine represents both safety- and health-related risks and effects and reacts quickly with organic matter to form DBPs, but such effects can be mitigated by applying a disinfectant with different characteristics. As a potential alternative, chlorine dioxide (ClO_2) is a strong and selective oxidizer and offers several advantages in treatment and distribution of drinking water. The ClO_2 forms fewer halogenated DBPs and can be used at lower concentrations and shorter contact times to achieve disinfection than is required for chlorine and chloramine disinfection. It is also less reactive to changes in pH than chlorine and has been proven more effective over a broader range of pH than free chlorine [1].

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The use of ClO_2 has been implemented in distribution systems since the 1970s after the discovery of total trihalomethanes (TTHMs) and other DBPs, which are still being discovered to date. It has been utilized in Europe and the United States as both a primary disinfectant and preoxidant, with around 1,200 plants currently implementing its disinfection [1]. The selective reactivity enables ClO_2 to control waterborne pathogens without reacting with organic DBP precursors. Unlike chlorine, ClO_2 reactions in water do not result in the formation of TTHMs and haloacetic acids (HAA_5) because "when ClO_2 oxidizes organic material, it is reduced to chlorite, but does not chlorinate the resulting organics" [2].

The ClO_2 can be applied for a variety of water quality issues, including DBP formation control, taste and odor issues, or nitrification in the distribution system, especially in distribution systems where water age within long dead-end mains is a concern [2]. The use of ClO_2 can be tailored to a specific facility's need; it can be used for the primary disinfectant or as a preliminary oxidant, followed by chlorine or chloramines, and has been shown to have five times stronger oxidation potential and disinfection efficacy than chlorine [3].

Regulatory guidelines, such as Florida Administrative Code (FAC) 62-555, identify ClO_2 as an acceptable method of inactivating viruses and bacteria to achieve 4-log virus inactivation. The U.S. Environmental Protection Agency (EPA) reg-

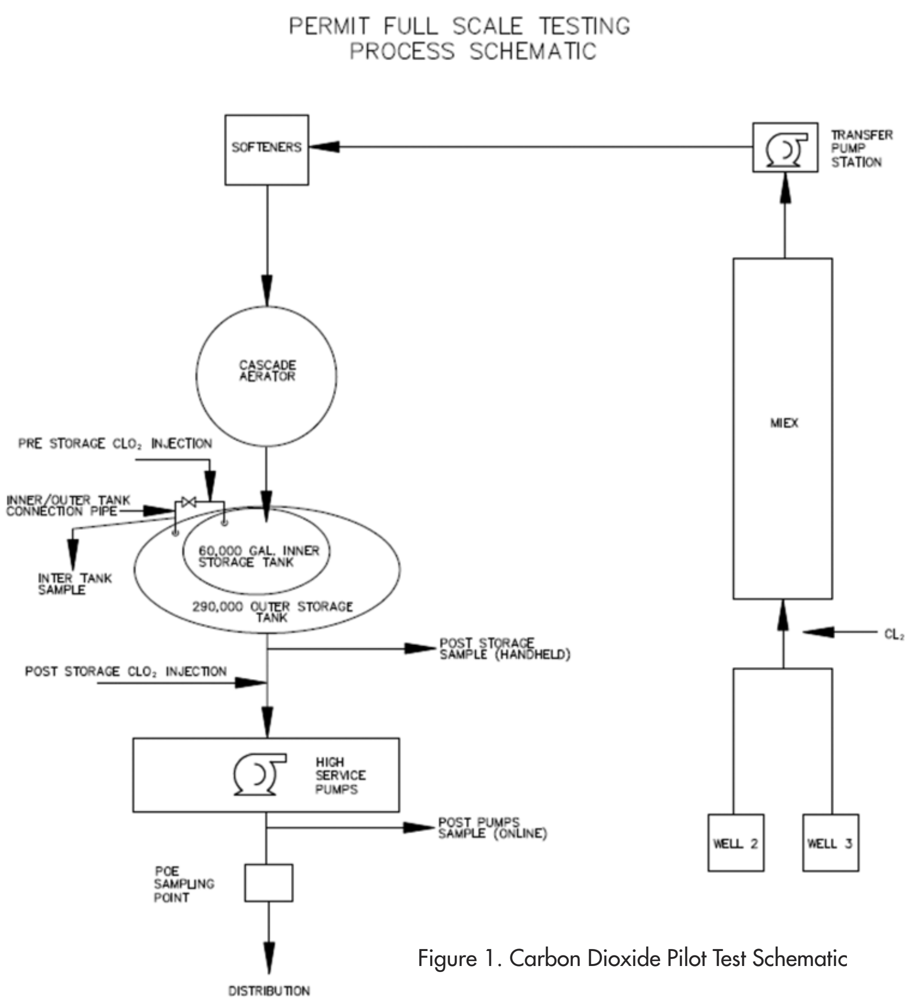

Figure 1. Carbon Dioxide Pilot Test Schematic

ulates ClO_2 as a primary disinfectant, with a maximum residual disinfectant level (MRDL) of 0.8 mg/L. When injected, ClO_2 dissociates in water to form chlorite, which has a maximum contaminant level (MCL) of 1 mg/L. Controlling chlorite levels to comply with the MCL is one of the keys to successfully implementing chlorine dioxide.

Chlorine Dioxide Generation Overview

There are multiple ways to produce ClO_2. Traditionally, chlorine dioxide was generated from the reaction of chlorine gas with sodium hypochlorite. Chlorine gas-based ClO_2 generation is not recommended, due to operational difficulty and safety concerns of handling chlorine gas. Recently, it has become increasingly common to produce chlorine dioxide through reaction of sodium chlorite with an acid, such as hydrochloric or sulfuric acid.

The primary methods of ClO_2 production are through an injection/eduction generator, or through combining powder components that contain stabilizers to minimize off-gassing of ClO_2 while stored. Regardless of the production method, ClO_2 should be produced within a 0.2-0.5 percent solution, to reduce risk of an exothermic reaction. The ClO_2 used in the pilot study (to be discussed) was produced from mixing two powder components, as supplied by Twin Oxide-USA LLC, with water forming a 0.3 percent ClO_2 solution.

Pilot Study

Preliminary Analysis of Need

Pluris Utility currently owns and operates the Wedgefield Potable Water and Wastewater Utility (utility). With the onset of the Stage 2 Disinfectants/Disinfection Byproducts Rule (D/DBPR), the utility attempted to maintain compliance with the DBPs through the MIEX® ion exchange treatment system to remove organics before disinfection. In recent quarters, the TTHM samples exceeded 80 parts per bil (ppb), increasing the rolling annual average of the sample sites to encroach upon the regulatory limit of 80 ppb. Prior to the study, the utility utilized sodium hypochlorite (chlorine) as the sole disinfectant for its storage and distribution system. Despite the utility's efforts to streamline the chlorine dosage and reduce the residual concentration, it was unable to achieve TTHMs below 80 ppb in the distribution system. Even at the lower concentrations, this disinfectant's reaction with the naturally occurring organics was producing a high level of TTHMs. As such, the utility sought alternative methods of treatment, as well as disinfectants to achieve compliance with the Stage 2 D/DBPR. Having experienced the maintenance-intensive operation efforts of chloramines and water quality concerns, the utility opted not to consider chloramine disinfection for this application.

Through field testing and laboratory evaluation of ClO_2 products, the utility decided to implement a full-scale pilot test within the distribution system. Field testing efforts included demand analysis testing at the water treatment plant, with onsite residual analyzers and demand curve identification. Further investigation included laboratory testing of chlorine dioxide injection, incubation, and sodium hypochlorite injection to simulate using chlorine dioxide as a preoxidant to chlorine disinfection. This testing was completed by the University of Central Florida (UCF) Environmental Systems Engineering Institute (ESEI) team and it revealed that this application was not suitable for the utility. After reviewing the results from this testing, additional laboratory testing was conducted to simulate chlorine dioxide being injected as the primary disinfectant, followed by incubation over a five-day water-age analysis. The results from this laboratory testing proved positive for the utility in support of a full transition to chlorine dioxide and the significant potential to reduce TTHMs within its distribution system.

The ClO_2 solution laboratory testing results revealed the apparent advantages of full disinfection without the negative DBP formation effects associated with chlorine. Full-scale pilot testing was predicted to have similar results, provided that the residual maintenance was achievable for the distribution system. A close watch on regulatory parameters was necessary to ensure compliance with the regulatory limits of chlorite MCL and chlorine dioxide MRDL.

The next step in the process was to demonstrate the laboratory effects on the full-scale utility system, and a pilot testing approval package was completed and submitted to the Florida Department of Environmental Protection (FDEP). While the chemical has been used in the utility industry, only a select few utilities have used chlorine dioxide as a primary disinfectant. Accordingly, several questions and comments were discussed with FDEP prior to garnering the approval to proceed with the pilot. Following approval from FDEP, the full-scale pilot test was implemented at Wedgefield's water treatment plant (WTP).

The overarching goals of the full-scale pilot study included a gradual transition from chlorine disinfection to chlorine dioxide, vigorous field and laboratory testing of the treatment process during the transition (and after) to ensure public safety, and compliance with the regulations. The utility and onsite staff completed extensive efforts to obtain all the required samples, and their thorough analysis and consideration of the results proved very helpful in concluding the effect of each process adjustment.

At the beginning of the pilot study, ClO_2 was injected into the ground storage tank in parallel with the current chlorine disinfectant dose. The ClO_2 residual in the distribution system was monitored to identify the attainment of the desired residual. Once the 0.2 parts per mil (ppm) ClO_2 residual was attained, chlorine dosage was trimmed slowly to perform the gradual disinfection transition. As chlorine was reduced, continuous monitoring of the ClO_2 residuals ensured the required 0.2 ppm minimum per FDEP's approval.

To assess the regulatory water quality compliance parameters, including the Stage 2 D/DBPR, multiple sample locations were identified within the distribution system; the utility's two compliance locations identified for HAA_5 and TTHMs were also included. Each sample location was monitored routinely for chlorine residual, ClO_2 residual, and chlorite concentration. The first formal location was chosen to be as close to the first customer as possible (20429 Mansfield St., Orlando, Fla.). The second formal location represents the average distribution system water age (20305 Majestic St., Orlando, Fla.). A third formal location was chosen to represent the maximum distribution system water age (19520 Glen Elm Way, Orlando, Fla.).

The pilot study sampling recorded the ClO_2

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residual at the point of entry (POE), averaging 0.43 mg/L, which is below the MRDL of 0.8 mg/L. The ClO_2 residual was at or above the minimum of 0.2 mg/L, in compliance with Florida Administrative Code (FAC) 62-555. The chlorite concentration in the distribution system ranged from 0.02 mg/L to 0.98 mg/L, resulting in an average concentration of 0.69 mg/L throughout the pilot study; the chlorite data is below EPA's MCL goal for chlorite of 1 mg/L. The MIEX system remained functional throughout the pilot study and will continue to be used to maintain low levels of organics and effective removal of hydrogen sulfide.

Overview of Pilot Setup and Equipment

The Wedgefield WTP includes two raw water wells feeding directly into the MIEX system, with a minor dose of sodium hypochlorite to mitigate biological growth within the contactor basins. The MIEX system removes approximately 60 percent of the total organic compounds and offers the additional benefit of approximately 95 percent removal of hydrogen sulfide. The MIEX-treated water flows to a clearwell and is then partially pumped through a softening system prior to combining for tray aeration and storage in the onsite ground storage tank. The ground storage tank consists of concentric tanks and is divided into an inner tank (approximately 60,000 gal) and an outer tank (approximately 290,000 gal). Produced water flows from the aerator to the inner tank and then through a single 12-in. pipe connection using a static differential between the inner and outer tanks. High-service pumps pull finished water from the outer storage tank to meet the potable demand. The treated water was disinfected using sodium hypochlorite immediately following the tray aerators, as the water collects in the inner storage tank.

The pilot study was designed to inject a premixed 0.3 percent ClO_2 solution downstream of the tray aerators and between the inner and outer ground storage tank to allow for backwashing of the onsite softeners from the inner tank, and prior to ClO_2 injection. The location was selected to utilize the hydrogen sulfide removal currently being achieved through the MIEX system and downstream of the softeners to prevent any oxidation of the softening media. As the water is transferred from the inner to the outer tank, chlorine dioxide is injected to achieve the primary disinfection for the finished water. See Figure 1 for a plant process schematic.

The dosage of ClO_2 was initiated at 1 ppm. Following injection, the ClO_2 residual was monitored using the handheld ClO_2 analyzer from the sample port installed on the pipeline connecting the inner and outer tank. After storage, ClO_2 was monitored via a handheld, as well as an online, analyzer for continuous readings as the water enters the distribution system. Additional monitoring in the distribution system was completed using the handheld analyzer.

The pilot program included the physical components to mix, store, inject, and monitor the ClO_2 disinfectant in the process stream. Given the powder supply chosen for chlorine dioxide generation, the pilot system was implemented to complete this pilot test. The specific components included the following equipment:

- *Product Mixing Tank*. A single 300-gal tank for mixing the two-component ClO_2 product and solution water.
- *Product Transfer Pump*. A single pump to transfer the fully mixed, 0.3 percent ClO_2 solution from the mixing tank to the storage tank.
- *Product Storage Tank*. Dual 600-gal tanks for storing the mixed ClO_2 product to supply the chemical metering pumps.
- *Inter-Storage Chemical Metering Pump*. A chemical metering pump dosing system, with flow-paced control (and residual alarm), to draw from the ClO_2 product storage tanks and dose the ClO_2 through one injector located at the pipe connecting the storage tank's inner and outer tank.
- *Post-Storage Chemical Metering Pump*. A chemical metering pump dosing system, with flow-paced control (and residual alarm), to draw from the ClO_2 product storage tanks and dose the ClO_2 through one injector located in the suction piping to the high-service pumps.
- *Sampling Stations*. Sampling taps located within the process to pull grab samples of the treated water immediately after injection and after storage in the outer tank.
- *Grab Sample Analyzer*. One Palintest handheld analyzer for routine monitoring of ClO_2 residual and chlorite at each of the sampling locations identified.
- *Online Chlorite Sample Analyzer*. One analyzer for continuous monitoring of chlorite levels at the POE to the distribution system.
- *Online ClO_2 Residual Sample Analyzer*. One analyzer for continuous monitoring of ClO_2 residual at the POE to the distribution system.
- *Online ClO_2 Monitoring and Control System*. One control panel capable of receiving the analog signals from the online analyzers, tank level monitoring, pump controls, and operator interface with the control system.

These physical components were inspected a minimum of two to four times per day as the operations staff completed its sampling efforts, as well as during the routine operation and maintenance of the existing treatment plant. Continuous operator monitoring and control was available through the internet-based supervisory control and data acquisition (SCADA) application for this system.

Optimization Plan

While starting up the chemical system, the utility staff closely monitored the residuals as the transition to ClO_2 extended through the distribution system. The ClO_2 chemical dosage was

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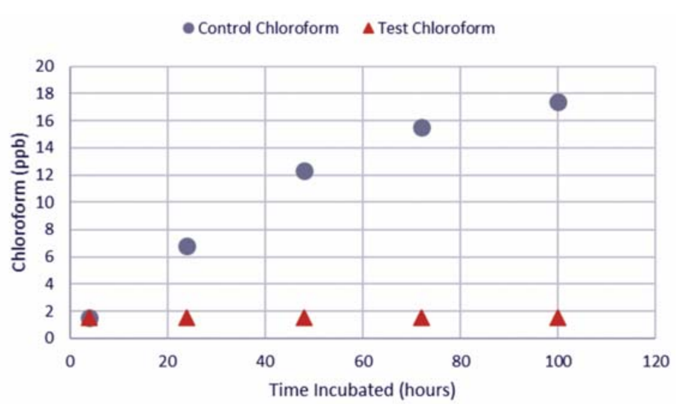

Figure 2. Chloroform Formation Potential

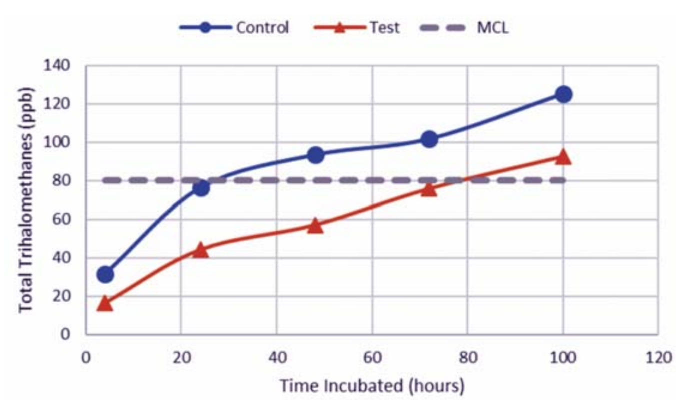

Figure 3. Total Trihalomethane Formation Potential

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initiated at 1.3 ppm based on the demand testing and laboratory analysis; the dose was increased if the desired 0.2 mg/L distribution system residual was not achieved. Due to the time delay between the dose and the POE sampling point, the ClO_2 dose was increased in 20-hour intervals or greater to ensure that the effective residual was monitored prior to any increased dosage. The ClO_2 residual was monitored throughout the distribution system to ensure that it had reached the extent of the distribution system prior to discontinuing the sodium hypochlorite injection.

Once the sodium hypochlorite injection was discontinued, the distribution system residuals were closely monitored to ensure that a stable ClO_2 disinfectant residual was maintained throughout the system. The dosage rate fluctuated at the beginning of the pilot in order to remain in regulatory compliance; it then leveled out towards the latter half of the pilot as the water quality stabilized.

Since the lag time between the injection in the inter-storage tank and post-storage tank sample was approximately 20 hours, a second ClO_2 dosing system was installed with the pilot equipment to boost the residual prior to entering the distribution system. The chemical injection pump was based on an online residual analyzer located downstream of the high-service pumps and feedback to the post-storage injection pumps. It was anticipated that this post-storage injection will decrease as the demand in the storage tank is reduced with the reaction of the initial ClO_2 dose. Both the inter-storage tank dosing pump and the post-storage dosing pump were alarmed with the respective residual analyzer to ensure that the 0.7 ppm high-residual alarm is not exceeded, keeping well below the MRDL of 0.8 ppm.

Once the dosage rate was identified and set to maintain the steady residual for each well supply, the pump settings were memorialized in the operational logs and records for the facility. The pump settings were adjusted based on the established start-up settings and trimmed based on the residual ClO_2 readings. While under operation, the operations staff continued to sample the residual through the sampling stations identified to maintain a steady residual throughout the distribution system.

The operations staff continuously monitored and recorded the ClO_2 levels at a minimum of two times per day within the eight hours of manned operation of the treatment plant. The handheld probes identified the ClO_2 levels that were used to confirm/regulate the feed rate of the ClO_2, thereby maintaining the desired 0.3 ppm residual level at the discharge of the outer storage tank. In the event that the ppm level exceeded 0.7 ppm of ClO_2 residual, the control system was set up to alarm and reduce the dosage pump until the residual returned to within the specified operating range.

Results and Observations

Preoxidant Evaluation

The bench-scale and laboratory testing revealed that the chlorine dioxide inhibits, reduces, and/or delays the formation of chlorinated TTHM species when dosed prior to chlorine, while the brominated species were unaffected with the chlorine dioxide preoxidation dose prior to chlorine. This was observed as the testing identified a reduced chloroform species of TTHMs and delayed the initiation of the formation curve by approximately 20 hours. Figure 2 displays the formation curve for the chloroform species. The "control" sample did not contain chlorine dioxide, whereas the "test" sample contained 1 ppm of chlorine dioxide, followed by chlorine. With Wedgefield's TTHM speciation driven mainly by brominated species, preoxidation was ruled out for this facility following the UCF ESEI analysis. Figure 3 details the delayed TTHM formation curve.

Chlorine Versus Chlorine Dioxide Transition

As with any pilot study, the planned operation rarely follows the scripted procedure. The utility and its hands-on operations team were instrumental in identifying changes and reporting the results that were observed. The initial dose of 1.3 ppm was quickly increased to address the demand on chlorine dioxide. It was noted that once the chlorine dioxide was introduced, the chlorine residual quickly began to rise and sustain chlorine residual within the distribution system. As the ClO_2 dose increased and reached through the distribution system, the operation staff was quick to adjust chlorine to account for the decreased system demand. The pilot study data showed that the stronger oxidant reacted with the system demand, leaving the slight chlorine dose to achieve the 0.2 ppm residual during the initial phases of the transition. As the ClO_2 residual achieved the minimum residual required for the distribution system, the chlorine dosage was gradually reduced and eliminated.

Chlorine Relationship to Chlorite

Chlorite was closely monitored throughout the entire pilot testing effort. A violation of the MCL was considered not acceptable for the pilot team and operations staff. The initial thoughts included a quicker transition from chlorine to chlorine dioxide, resulting in a clean and crisp transition. As the chlorine dosage was eliminated, the chlorite readings began to rise and it appeared that even the slightest dose of chlorine reacted with the chlorite to form chlorine dioxide, reducing the chlorite formation quickly back to a lower level. After several attempts, the utility operations staff was able to reduce the chlorine dosage using a smaller dosage pump, which made the transition less impactful for the chlorite readings.

Batch Solution Quality and the Effects on Chlorite Monitoring

The utility staff identified a potential chlorite influence to be the makeup water for chlorine diox-

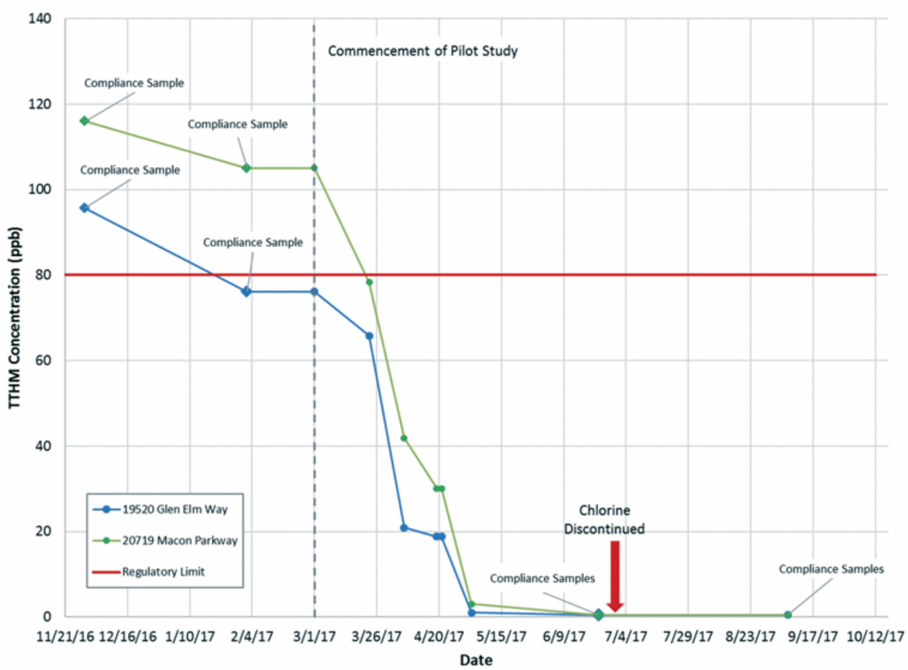

Figure 4. Total Trihalomethane Results

ide. The hypothesis included that the purer the makeup water, the less chlorite will be formed and analyzed through the POE sample. To test the hypothesis, the operations staff installed a reverse osmosis unit to purify the feed water for the makeup solution. While the quantity of chlorite analyzed didn't dramatically reduce, it was noted to be much more consistently measured with the online analyzer. At the low demand needed for makeup water, the utility continues to utilize the reverse osmosis unit to pretreat the makeup water prior to mixing the chlorine dioxide batches.

Total Trihalomethane Reduction

The pilot study results confirmed that the combination of ClO_2 and chlorine as dual disinfectants was effective in reducing TTHM and HAA_5 concentrations. Additionally, ClO_2 as a primary disinfectant proved to be very successful in reducing TTHM concentrations and moderately successful in reducing HAA_5 concentrations in the distribution system since the transition off chlorine was completed. The distribution system was measured for TTHM and HAA_5 concentrations at both compliance locations (19520 Glen Elm Way and 20719 Macon Pkwy) for process monitoring samples and compliance samples. Figures 4 and 5 demonstrate the compliance results from the two prior compliance samples through the first 90 days of the pilot study.

Figure 4 displays the results for TTHM sampling events during the pilot study, as well as the two compliance samples, prior to initiating the pilot study. The TTHMs declined from over 110 ppb at Macon Pkwy (November 2016) to 20 ppb (about two months after commencement) and were nondetectable by June 2017 near the end of the 180-day pilot. The TTHMs were also undetectable in the September 2017 compliance samples, demonstrating the predicted results of nondetectible TTHMs. A similar curve was observed for the Glen Elm Way sampling site.

Haloacetic Acids Reduction

Unlike the reduction in TTHMs, the HAA_5 concentrations also showed a reduction over the course of the study, but took a less linear approach. As shown in Figure 5, the two previous HAA_5 compliance samples were well within the 60-ppb compliance limit. Over the course of the study, an increase in HAA_5 was observed early in the study, followed by a steady decrease to slightly below 40 percent reduction of the prestudy results on Macon Pkwy and approximately 65 percent reduction on Glen Elm Way.

Regulatory Compliance

It was imperative to the utility that all regulations were met through the entire piloting period. As such, special emphasis and attention was given to the chlorine dioxide MRDL and the chlorite MCL. Early control and dosing were challenged through the programming features of the control system; therefore, the chlorine dioxide residual fluctuated significantly over the first few weeks of operation. Following discussions with the operations staff regarding the control system features, a new control system was implemented to facilitate more-accurate control measures, which enabled the operations staff to hone in on the chlorine dioxide residual. Similarly, the chlorite monitoring suffered inconsistencies early in the study and became more consistent through the latter half of the pilot study.

Meeting Chlorite Residual Standards

Laboratory results and field analysis samples taken with the Palintest handheld analyzer confirmed that chlorite levels were maintained below the MCL of 1 ppm throughout the pilot study. The peaks shown in Figure 4 are correlated to the

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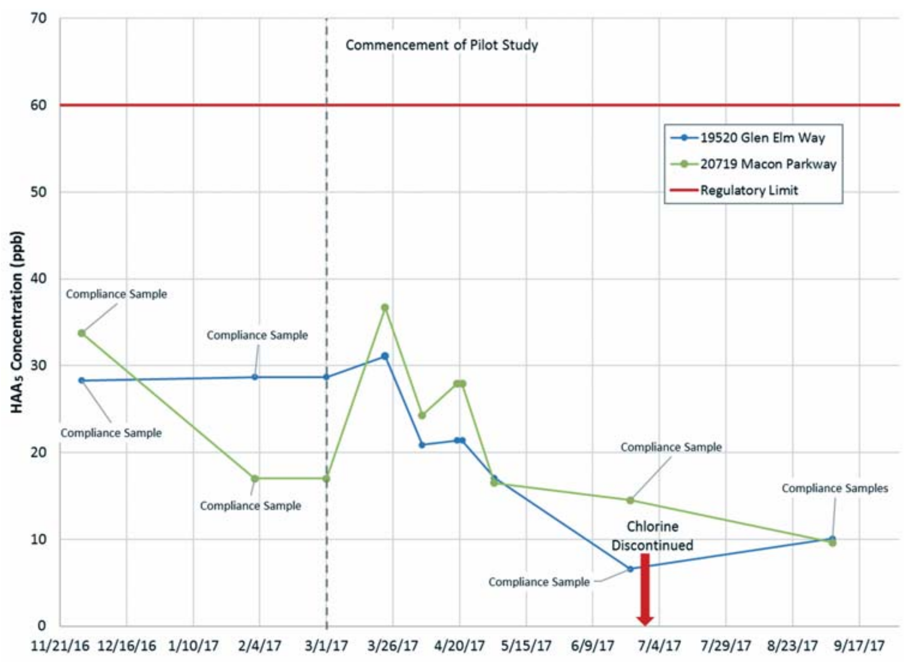

Figure 5. Haloacetic Acids Results

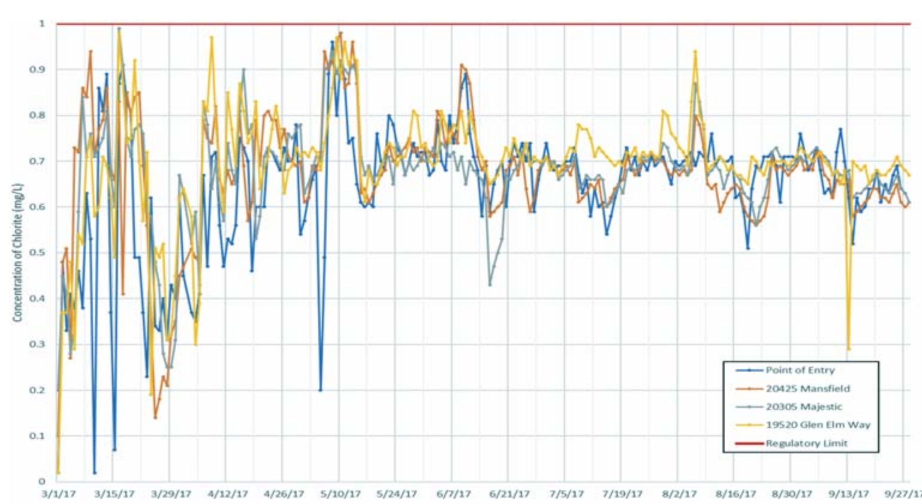

Figure 6. Chlorite Residual Results

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attempts to discontinue the chlorine injection; as noted, the chlorine injection had a noticeable effect on the chlorite analysis. Figure 6 displays the daily recorded chlorite concentrations and reveals the fluctuations during the commencement of the study, and ultimately leveled off between 0.6-0.8 ppm, well below the MCL of 1 ppm.

Meeting Chlorine Dioxide Residual Standards

Chlorine dioxide was closely monitored to maintain compliance. Daily data from the ClO_2 residual results from the pilot study are shown in Figure 7. The residual levels shown dropped below the 0.2 ppm residual towards the beginning of the pilot sampling and peaked shortly after. There were only two instances where the chlorine dioxide residual at the POE exceeded 0.8 mg/L, which were due to calibration events and subsequent erratic readings by the online analyzer. Once the control and injection system was modified by the utility's SCADA contractor, the ClO_2 results were stabilized to a level consistent with regulations by the end of the data recorded.

Residual Considerations

A chemically stronger oxidant than chlorine, ClO_2 possesses a higher efficacy in virus inactivation [4]. Theoretically, a lower ClO_2 disinfection residual could be maintained and still provide the same level of protection as the regulated free chlorine residual of 0.2 mg/L. Prior to, and during the 90-day study, FDEP's regulations required an "equivalent" ClO_2 residual, which was originally interpreted by regulators to mean 0.2 mg/L; therefore, the chlorine dioxide residual in the distribution system was maintained above 0.2 mg/L throughout the pilot study, which required a chlorine dioxide residual of approximately 0.4 mg/L at the POE.

The high residual required at the POE increased the amount of chlorite produced, making it a challenge to maintain the minimum residual while remaining below the chlorite MCL of 1.0 mg/L. After conducting desktop research, interviewing chlorine dioxide manufacturer representatives, investigating the chlorine dioxide history for both the City of Hamilton and Mount Vernon in Ohio, and gaining an increased understanding of ClO_2 effects within the distribution system, the utility and Kimley-Horn requested that the ClO_2 residual be lowered to 0.05 mg/L, which was later approved by FDEP. The extended pilot study will operate at the 0.05 mg/L minimum residual within the distribution system. The lowered required residual opens the door for other Florida utility providers to investigate ClO_2 as a primary disinfectant, lowers the concentration of chlorite in the drinking water, and decreases the amount of ClO_2 the utility needs to produce.

Conclusion

The overall goal of this study was to reduce DBP formation within the Wedgefield community and maintain compliance for the utility. Data collected during the study revealed 99 percent reduction in TTHMs and approximately 50 percent reduction in HAA_5 for the initial 120-day period of the pilot testing. These results proved the effectiveness of chlorine dioxide in reducing the TTHMs for the utility. As a disinfectant, the utility has not experienced any adverse issues within the distribution system due to the transition from chlorine to chlorine dioxide.

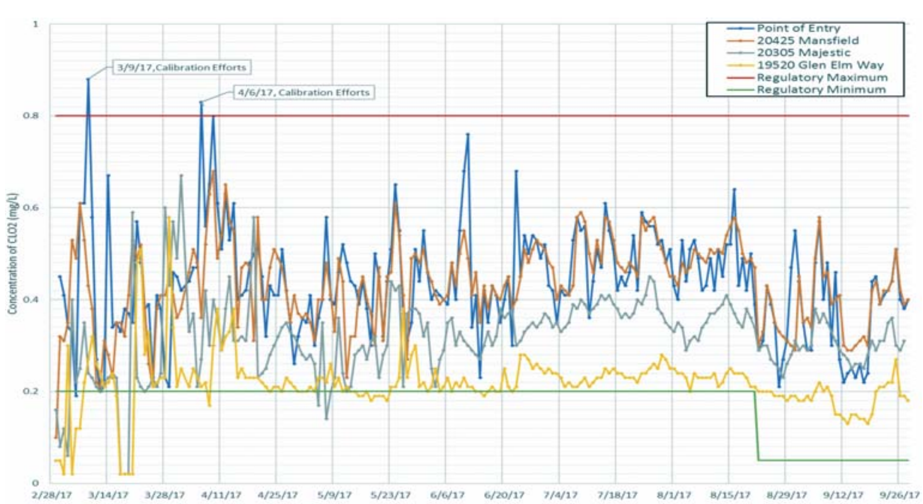

Figure 7. Chlorine Dioxide Residual

Recommendations

The ClO_2 proved to be highly effective at minimizing DBP formation, while saving capital costs compared to treatment upgrades; however, ClO_2 is relatively uncommon for potable water applications, so it's imperative to fully understand the process before investigating its use. The following recommendations are based on lessons learned from the Wedgefield pilot study and ongoing pilot studies:

- ClO_2 is proven to be an effective tool to maintain compliance with Stage 2 D/DBPR, but it is still recommended to perform field and laboratory testing to verify the compatibility with the desired water. A full- or pilot-scale study is recommended prior to installation of a permanent chlorine dioxide system to evaluate the effects within the distribution system. The goals of a pilot study would be to reveal the effects of chlorine ClO_2 on a system's specific water quality and identify optimal ClO_2 dosing for maximum cost savings. Based on pilot study results for the utility, the chlorine demand of the system will fluctuate as the ClO_2 infiltrates and reacts with existing biofilm in the pipeline; it's anticipated that the chlorine dioxide demand will then reduce and remain constant as the biofilm is cleaned out of the system. Consideration to ClO_2 nonorganic byproduct of chlorite ion should be maintained under EPA's MCL limit of 1 mg/L entering the system. Granulated activated carbon, or a chemical addition such as ferrous chloride or ferrous sulfate, can also be used to combat the chlorite.
- It is important to gain understanding and consensus from state and local regulators and to remain in compliance with all water quality regulations while performing a chlorine dioxide pilot study. Chlorite levels in the distribution system must be monitored regularly and maintained below the MCL. It's recommended that the chlorine dioxide and chlorite samples are being accurately assessed from either a laboratory or a handheld sample analyzer. Inaccurate test results and wrongly reported concentrations can affect regulatory compliance and cause unnecessary public concern.
- It is recommended to understand and review available options for chlorine dioxide generation. Several factors are important when understanding generation options, including operator training and availability, goal usage of chlorine dioxide, redundancy needs, and chemical safety. Moreover, the aspects of each generation system need to be compatible with the process application and utility production conditions. Generators often produce chlorine dioxide on demand; however, chlorine dioxide storage is not often available for these units.

- Proactive and direct public communication is recommended before chlorine dioxide is used as a disinfectant. Although chlorine dioxide technology is not new, the public may be concerned when learning of the use of an unfamiliar chemical. It's important to emphasize the benefits of chlorine dioxide and compare the safety of chlorine dioxide to typical disinfectants.

Final Considerations

All in all, careful consideration should be given to the implementation of chlorine dioxide within a water production or distribution facility. While the chemical is effective in maintaining disinfectant residuals, as well as improving aesthetics in distribution system water quality, the appropriate process addition may be as a preoxidant, rather than as the primary disinfectant.

Chlorine dioxide has shown promise as a strong disinfectant chemical for other utilities aspiring to reduce DBPs without incurring the significant capital costs associated with high-end treatment or the routine maintenance challenges with chloramines. As a viable alternative disinfectant, it should be considered when these DBP or distribution system challenges are present.

Acknowledgments

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