Reducing Disinfection Byproducts (DBP) at the Stones River Water Treatment Plant in Murfreesboro, TN

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Background

Analyzing historical Stage 1 Disinfection Byproduct Rule (DPBR) sampling data for the Murfreesboro Water and Sewer Department (MWSD) indicated compliance with the more stringent federal Stage 2 DBPR could be a challenge at some locations in the distribution system. Therefore, staff at the Stones River Water Treatment Plant (SRWTP) and Smith Seckman Reid, Inc. (SSR) conducted a study of the water treatment plant (WTP) and distribution system aimed at reducing disinfection byproducts.

The federal Stage 2 DBPR (effective October 2012) maintains the same maximum contaminant levels (MCLs) for both total trihalomethanes (TTHM) and haloacetic acids (HAA5). MCLs remain unchanged at 80 µg/L and 60 µg/L for TTHMs and HAA5, respectively. However, the new regulation changes compliance calculations to a locational running annual average (LRAA) from a system-wide running annual average. This change requires each individual sampling site to comply with MCLs calculated by averaging the last four (4) quarterly samples.

Plant operational records between February 2008 and November 2011 showed consistently elevated quarterly TTHM levels at one location in the distribution system. During this time period, a single-day maximum of 182 µg/L and a 7-day maximum of 168 µg/L were recorded at this location. Figures 1 and 2 show the calculated LRAA from historical TTHM and HAA5 sampling data for Stage 1 DBPR compliance at this sampling point of concern. The solid line indicates the compliance threshold for TTHM and HAA5 under the Stage 2 rule. The LRAA values calculated were not

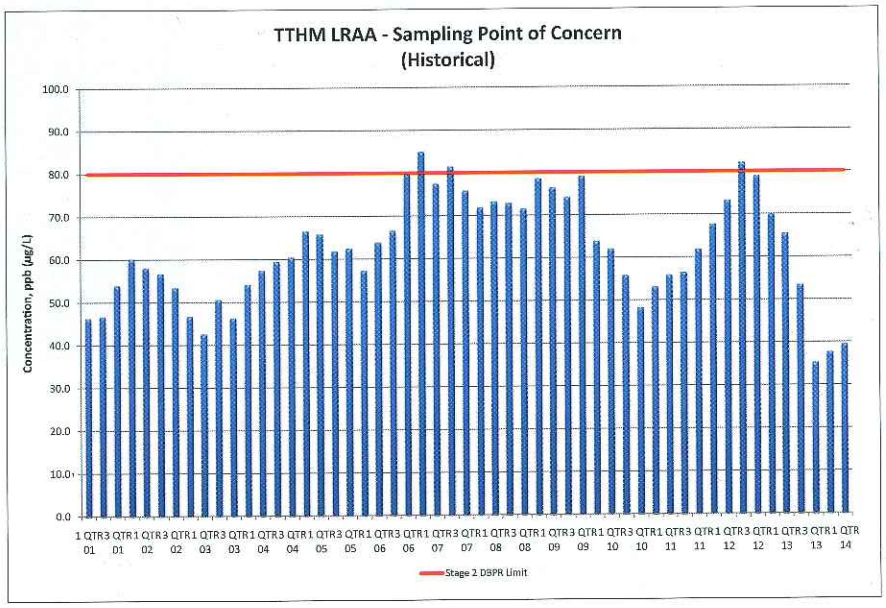

Figure 1

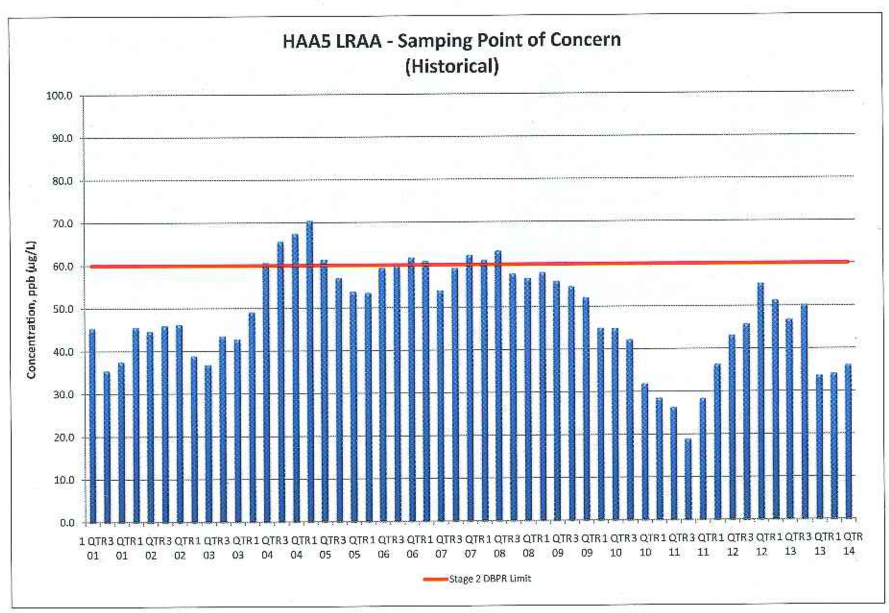

Figure 2

required or reported for Stage 1 DBPR compliance. These values were calculated to evaluate the potential difficulty MWSD might have meeting the tighter regulations of the Stage 2 rule without additional treatment technologies.

Given the anticipated difficulty in meeting compliance requirements of the Stage 2 rule, a brainstorming session was conducted including management staff, operations and maintenance personnel, and engineers. Roughly a dozen alternatives were proposed at that session; however, all but three were excluded from further consideration due to potential adverse effects. The three alternative solutions examined in the study included: (1) feeding hydrogen peroxide at the plant in lieu of sodium hypochlorite for pre-oxidation, (2) replacement of GAC contactor media more frequently, and (3) aeration systems in the distribution tank(s).

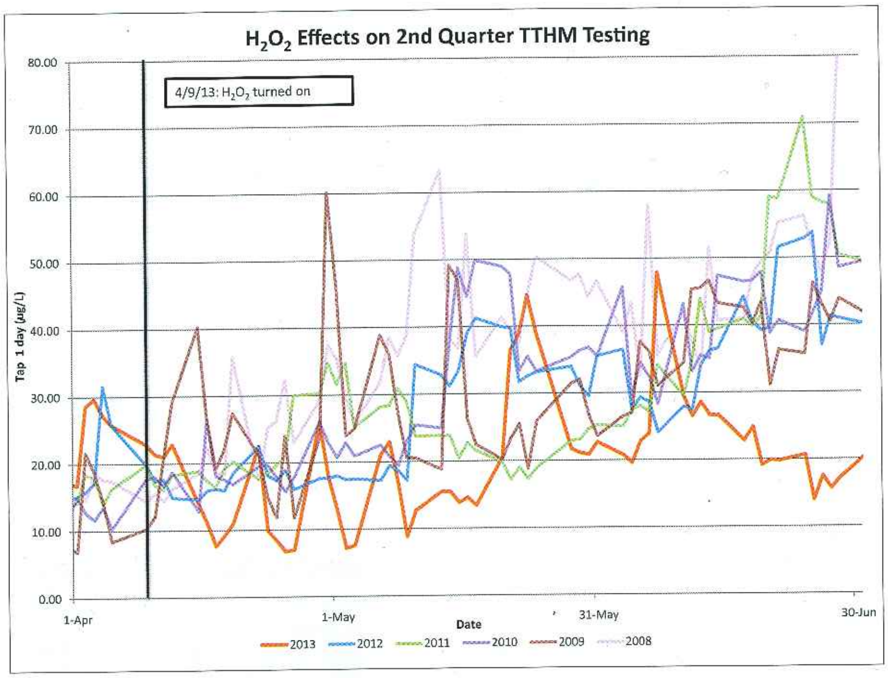

Figure 3

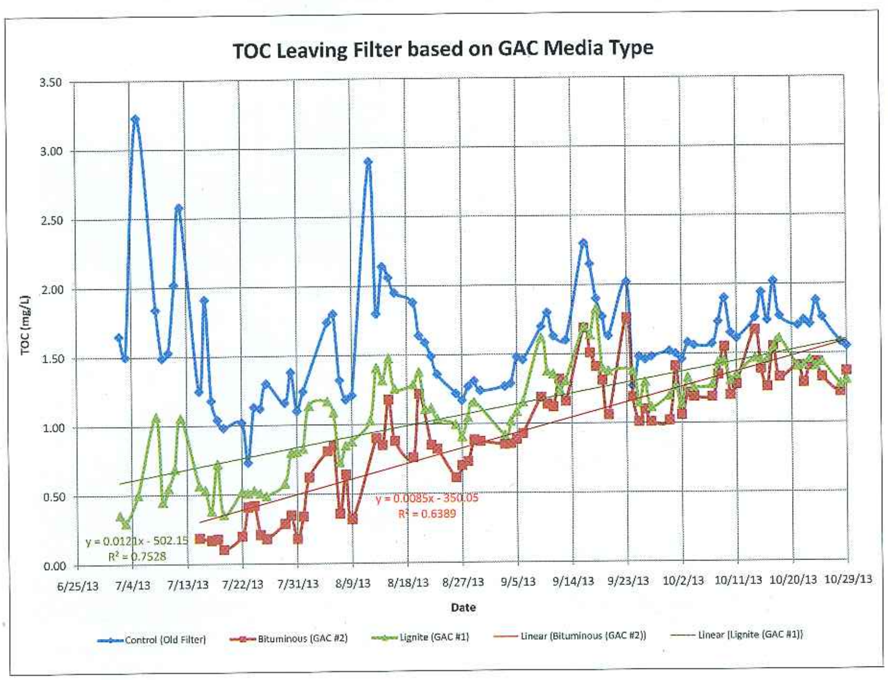

Figure 4

Hydrogen peroxide

Hydrogen peroxide is a strong oxidant used as a pre-treatment chemical for algae control, mitigation of taste and odor issues, and iron oxidation. Recently, hydrogen peroxide has shown promise at reducing concentrations of disinfection byproducts in the treated water. Unfortunately, its efficacy is difficult to predict, and certain facilities see limited benefit.

Hydrogen peroxide was piloted at the plant in the sedimentation basins and in the combined settled water as an alternate oxidant to sodium hypochlorite. The trial dosages varied from 0.30 ppm to 0.65 ppm. Preliminary results showed hydrogen peroxide reduced TTHM levels in combined settled and GAC filtered water samples. Though not specifically targeted in the study, hydrogen peroxide also improved HAA5 levels in the combined settled water.

Distribution data was more ambiguous, however. The application of hydrogen peroxide did not immediately decrease DBP levels in the distribution system; rather it seemed to prevent concentrations from peaking to historical levels seen in previous years. Review of historical TTHM data from the past five years shows that TTHM levels trend higher in the second quarter. In 2013, the second quarter TTHM data shows a substantial decrease in the byproduct level compared to historical levels as shown on Figure 3. As the media in the two GAC contactors had not been replaced during the pilot program, the reduction of the TTHMs is likely attributed to the introduction of hydrogen peroxide into the treatment process.

Granular activated carbon (GAC) replacement

The reduction of TTHM and HAA5 species through GAC contact is well documented. However, because the removal mechanism is adsorption, all carbon contactors have a finite removal capacity. Once this adsorption capacity is depleted, costly reactivation or replacement of the carbon material is necessary to re-establish DBP removal objectives. Four (4) GAC contactors are operated at the SRWTP. The contactors

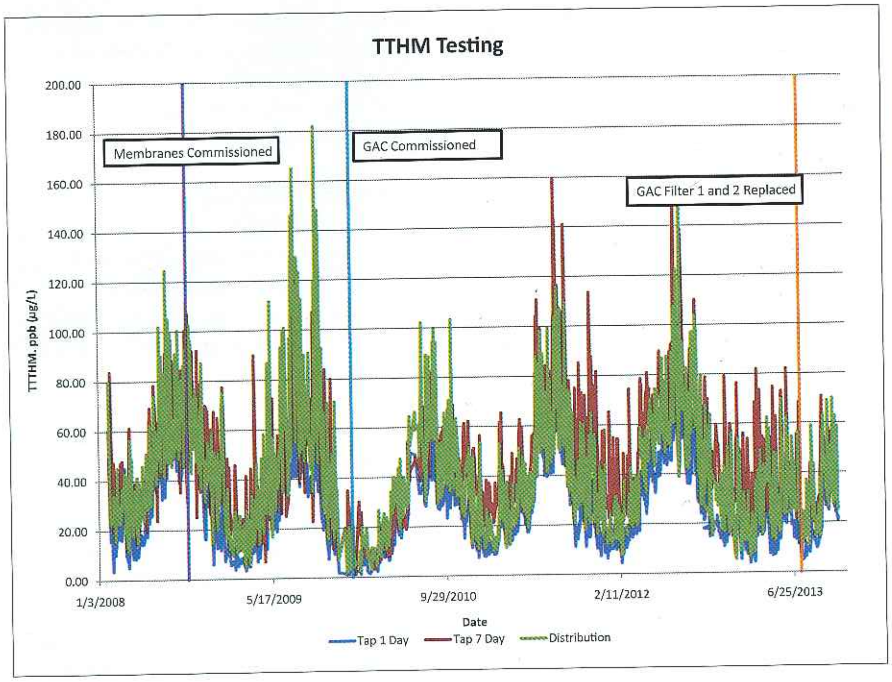

Figure 5

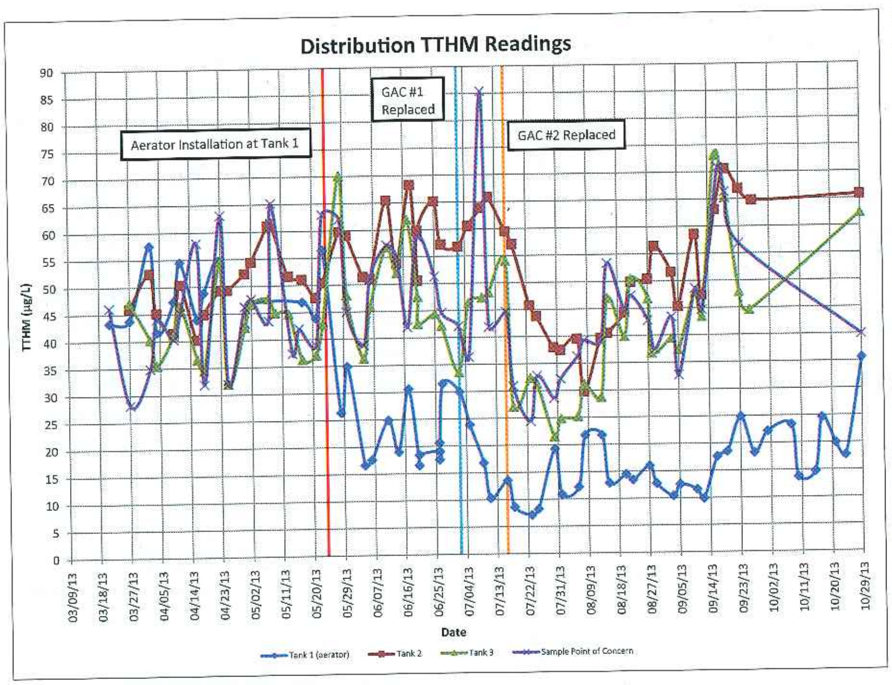

Figure 6

were commissioned in 2009 with virgin media, however the media had not been replaced or regenerated in four years.

The plant replaced media in contactor No. 1 with a lignite based media on July 2, 2013 and GAC contactor No. 2 with a bituminous based media on July 14, 2013. Because total organic carbon (TOC) is a DBP precursor, a reduction in TOC levels leaving the plant reduces the likelihood that TTHM formation will be observed in the distribution system. The study measured TOC levels on the inlet and outlet of both contactors with new media and a control contactor (i.e., contactor without new media). Figure 4 demonstrates the substantive but finite TOC adsorptive capacity of the GAC media.

Test results indicate that the TOC adsorptive capacity of both new carbon materials is consumed within three to four months of replacement. As shown in Figure 4, the lignite material demonstrated a slightly faster rate of decline than the bituminous material. Based on this study, replacing GAC media can significantly reduce DBP precursors for a narrow window of time before media replacement is necessary.

Additional analyses of TTHM readings from the distribution system confirm GAC's positive impacts on disinfection byproducts. Again, this benefit is limited by the carbon's remaining TOC absorptive capacity. As shown in Figure 5, significant drops in TTHMs were measured when the four GAC contactors were originally commissioned in 2009 and when media in two (2) contactors were replaced over the course of this study.

In an effort to identify a less expensive alternate to traditional regenerating methods, SRWTP evaluated a new chemical that claims to regenerate the carbon in-situ, thus eliminating a significant component of the regenerating cost. Initial results from this study indicate the new chemical did not achieve any significant amount of regeneration on the carbon material currently installed at the plant. The chemical manufacturer attempted regeneration a second time, but little improvement in adsorption capacity was realized. The manufacturer attributes the poor performance of their chemical to the lignite-based GAC used at the plant. The chemical manufacturer stated their previous successes at other water treatment plants around the country were achieved regenerating bituminous-based carbon. The manufacturer also theorized that carbons with low iodine numbers (i.e., iodine number of 500) utilized at the SRWTP do not regenerate as well with their chemical as other carbons with higher iodine numbers (i.e., iodine number of 900). The study will be repeated this year again to see if better results can be obtained.

Aeration in distribution system

Chloroform (one of the regulated THM species) has a high Henry's Law constant (3.67x10-3 atm m3/mol). Given this chemical property, chloroform can be easily stripped from finished water with aeration. Because Henry's Law constants for HAAs are several magnitudes smaller than THMs, removal of HAAs via aeration is not as effective.

In Murfreesboro, chloroform is the main contributor to total TTHMs. Within the last three years, chloroform levels exceeding 100 µg/L and 60 µg/L have been documented in the distribution system and SRWTP clearwell, respectively.

One Stage 2 compliance location in the distribution system is of particular concern. This location currently hovers near the limit set forth by the Stage 2 DBPR. SSR utilized MWSD's hydraulic model to analyze the influence zones of four distribution storage tanks that could impact TTHM levels at the compliance location in question. A pilot study of a two-part aeration and mixing technology was conducted at the storage tank identified with the largest influence on the area of concern.

The results obtained from the pilot study, shown in Figure 6, demonstrate the aeration technology's ability to reduce TTHM levels significantly in the treated storage tank. However, the reduction seen at the aerated tank did not correlate to a similar reduction at the compliance location of interest or any of the other sample locations tested in the system over the course of the study. This appears to be related to the hydraulic configuration of Murfreesboro's distribution system. Because all of the storage tanks 'float' on the same pressure system and their geographic location, a significant portion of the water at the location of interest never travels through one of the storage tanks. Consequently, even if every one of Murfreesboro's storage tanks was aerated, the expected overall TTHM reduction in the distribution system would not be reduced enough to ensure compliance. For these reasons, aeration technology does not appear to be an effective alternative to reduce TTHM levels in the Murfreesboro distribution system.

Study conclusions

Based on the results of the hydrogen peroxide study, a permanent chemical feed system designed for reducing both TTHMs and HAA5s will be installed at the plant. The addition of hydrogen peroxide will also reduce the chlorine dosed at the plant. Because free chlorine is one reagent in forming DBPs, reducing the amount of chlorine fed at the plant should also positively impact the formation potential for DBPs in the distribution system.

Granular activated carbon has proven effective at reducing DBPs in Murfreesboro's potable water system. Additional benefits are also achieved through GAC treatment including taste and odor reduction, volatile and synthetic organic compound reduction, and microconstituent reduction.

The GAC reaches its adsorptive capacity for different compounds at different rates, but in general it should be replaced every three to five years based on continued taste and odor reduction. SRWTP has four GAC contactors, and plans to replace one of the contactors every year. Furthermore, SRWTP plans to re-evaluate a new chemical that claims to regenerate the carbon in-situ, and thus eliminate a significant component of the regeneration cost. SRWTP will pilot this chemical on the bituminous-based GAC one year after installation.

Based on the distribution tank aeration study, a permanent aeration system will not be installed.