Online THM Analyzer Integral to City of Benicia's Stage 2 DBPR Compliance Strategy

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ABSTRACT: The City of Benicia, California, implemented a series of best management practices to help minimize the formation of trihalomethanes (THMs) in their distribution system and ensure regulatory compliance. In addition to minor pre-treatment and disinfection process changes, the Benicia Water Treatment Plant (WTP) decided to monitor THM levels more frequently using the online THM analyzer, THM-100™, to provide accurate and timely information regarding THM levels in their treated water. Integrating the online THM-100 analyzer at Benicia WTP has become an essential element to help support the delivery of treated water of the highest quality.

INTRODUCTION

The City of Benicia, a small full-service city in the San Francisco Bay Area, must address high levels of dissolved organics in their source water while servicing the water treatment needs of approximately 28,000 residents through a nominally rated 12 million gallon per day (MGD) conventional treatment facility. With access to two water sources, the primary source water for the Benicia Water Treatment Plant (WTP) contains high levels of natural organic matter (NOM) with total organic carbon (TOC) levels ranging between 4-18 mg/L.

While the Benicia WTP has successfully and continually reduced TOC levels by approximately 50% through pre-treatment efforts, residual TOC combines with the chlorine gas disinfectant used onsite to form moderate levels of trihalomethanes (THMs) leaving the WTP. The City of Benicia has implemented a series of best management practices to help minimize the formation of THMs in their distribution system and to ensure compliance with the Stage 2 Disinfectants and Disinfection Byproducts Rule (DBPR).

In addition to minor pre-treatment and disinfection process changes, the Benicia WTP decided to monitor THM levels more frequently and chose to use an online analyzer to provide accurate and timely information regarding the THM formation in the treated water. Monitoring THM levels with an online analyzer has enabled the WTP to optimize enhanced coagulation and disinfection residual based on the Total THM concentration reported throughout the day.

The online THM analyzer has been fully integrated into the THM control strategy after nine months of continuous use; serving as an essential element to ensure Stage 2 DBPR compliance.

TREATMENT CHALLENGES

Located in the southern part of Solano County, raw water for the Benicia WTP primarily comes from two surface water sources originating 50 miles away from the WTP. The first is from the North Bay Aqueduct (NBA), an extension of the State Water Project; and the second is the Solano Project, a Federal water project that created Lake Berryessa and the Putah South Canal delivery system. A third raw water source is the City-owned Lake Herman, which serves as an emergency source of water with approximately 30-days of storage during highest demand.

Shortly after being commissioned in 1971, the Benicia WTP switched from Lake Herman and began receiving water from the Solano Project. The Solano Project delivered a source water low in NOM (dissolved organic carbon is approximately 50% of the TOC loading). In 1988, the North Bay Aqueduct came online and the Benicia WTP made this their primary source due to ample quantity and generally good water quality. The NBA delivered significantly higher levels of NOM, especially after heavy precipitation runoff with dissolved organics representing 80% of the TOC loading.

Operated by the California Department of Water Resources, the NBA originates at the Barker Slough Pumping Plant, west of the Sacramento River above Rio Vista, and terminates at the Cordelia Forebay. The NBA watershed is surrounded by agricultural lands, predominantly for cattle grazing and grain fields. The soil has a significant clay morphology, which does not promote percolation after precipitation. As a result, runoff during rainfall causes sheet washing of NOM into the Barker Slough pump station. Furthermore, a privately owned stock pond, Campbell Lake, is located upstream of the Barker Slough Pumping Plant. Campbell Lake contains high levels of NOM and blue-green algae that flushes into Barker Slough and causes TOC levels to increase during the months of December through March; although continued runoff from the surrounding foothills delivers high NOM concentrations well into May. High levels of NOM in source waters are a precursor for the formation of disinfection by-products such as THMs.

The higher levels of NOM in the NBA source water posed a major challenge as the city worked to comply with the Trihalomethane Rule of 1979. TOC levels of the NBA source water ranged from 4-18 mg/L and pre-treatment efforts successfully reduced these levels by approximately 50%. Enhanced coagulation accounted for approximately 40% of the reduction and absorption with granular activated carbon (GAC)/sand dual media filters accounted for approximately 10% of the reduction.

A summary of THM levels at the Benicia WTP from January 2008 through October 2012 can be found in Figure 1. THM speciation is composed of approximately 80% chloroform ($CHCl_3$), followed by 20% bromodichloromethane ($CHCl_2Br$), 0% dibromochloromethane ($CHClBr_2$) and approximately 0% bromoform ($CHBr_3$).

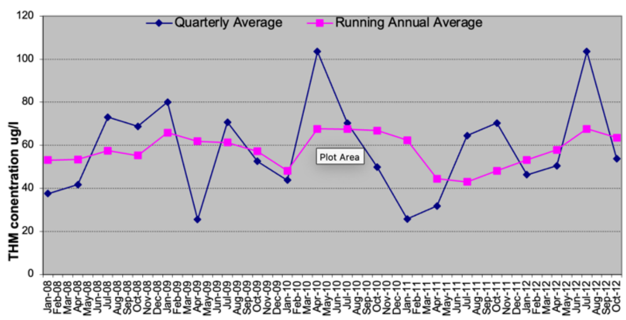

Figure 1- Benicia Water Treatment Plant THM Summary

TREATMENT APPROACH

The Benicia WTP employs a conventional treatment process including coagulation-flocculation, sedimentation, GAC filtration, and chlorine gas disinfection. While the WTP is nominally rated at 12 MGD, maximum demand rarely exceeds 10 MGD. Typical flow during the summer is approximately 8 MGD and during the winter months it is 3.5 MGD. The annual average flow is approximately 6 MGD, matching the demand of users served by the system. Any surplus or deficit is buffered by the storage capacity of the reservoirs. Storage in the distribution system was designed to handle fire demands (approximately 50% of storage capacity), daily demand (approximately 25% of storage), and peak demand (the remaining 25%).

Despite a 50% reduction of TOC levels, operational costs to further reduce THM levels included alum sludge removal annually, granular activated carbon replacement every six years, and switching over to Solano Project water during the winter months because of the high NOM in the State Water Project NBA source. Pumping Solano Project water to the Benicia WTP includes the higher cost of water and the electrical energy for the 200-HP motors.

In 1994, the Benicia WTP commissioned a study to evaluate the possibility of blending source water from NBA and Solano Project so the influent quality reaching the plant would contain lower levels of NOM. The study showed adequate pump capacity to accommodate blending of the two source waters during the problematic months of December through March when TOC levels in the NBA source water were highest. With the advent of the Enhanced Surface Water Treatment Rule, operators at the Benicia WTP already working to reduce TOC levels through source water blending and during pre-treatment process stages began to focus efforts on reducing THMs leaving the plant and minimizing the formation of THMs in the distribution system.

In 2004, the city explored primary treatment alternatives to reduce THM levels in their distribution system. The possibility of employing a stronger oxidant such as ozone or chlorine dioxide in the treatment process was evaluated; however, this approach was not implemented due to high process economics and the level of operational complexity required. Tying up the free chlorine residual with ammonia to form chloramines in the distribution system was also evaluated. While the Benicia WTP has a chloramination system onsite, it chooses not to operate it at this time because of the impact of chloramine breakdown in the distribution system.

Instead of altering their treatment processes, the Benicia WTP looked to employ best management practices (BMPs) for THM control and strategy using their existing schemes. The WTP staff maintained "super" enhanced coagulation through the use of acidified alum, controlled the disinfectant of filter effluent to minimize the amount of free chlorine in the system, turned over the reservoirs on a daily basis to reduce water age, flushed the distribution system on a weekly basis, and replaced GAC media every six years. However, real-time fluctuations in THM levels resulting from source water or process control changes were difficult to characterize based on the frequency of quarterly grab samples and subsequent analysis. Furthermore, once issued to external laboratories for analysis, results would take upwards of 10 days to be returned. The turnaround time proved too long to implement proactive management of THM mitigation strategies.

Monitoring the real-time correlation between operating conditions and THM formation potential was imperative. Some locations throughout the distribution system were experiencing high levels of THMs due to residence time and the age of water conditions. As the utility began to explore the costs associated with issuing two daily samples to an external laboratory for analysis, they learned about an online THM analyzer capable of providing immediate results and measurements for Total THM and the chloroform specie via an automated colorimetric process. As a result, the Benicia WTP entered into a three-month bench trial to study the effectiveness of using the THM-100™ online analyzer from AMS to accurately measure THM levels in finished water leaving the facility.

The automated online THM analyzer uses an approved "purge-and-trap" sampling method, followed by desorption into a chemical mixture that generates a colored product and time-resolved spectrophotometric analysis for detection and determination of THM levels. Typically scheduled to take measurements every four hours, the Benicia WTP set the self-calibrating system to sample every four hours (0200, 0600, 1000, 1400, 1800, and 2200) so it would coincide with other water quality measurements and sampling scheduled at the facility.

Shortly after installing the online THM analyzer in October 2012 and establishing baseline THM data, the utility began to undertake weekly process changes to determine the effect on THM levels. The controlled experiments only included the testing of conditional changes that would improve water quality, since testing of conditions that might have a detrimental effect on water quality would hinder the ability to provide high quality water to the customer base.

Prior to undertaking the controlled process changes though, the accuracy of the online monitor and its repeatability against certified laboratory data was verified. Results in Figure 2 and Figure 3 show the precision and bias of the online THM analyzer yielded better results than laboratory methods.

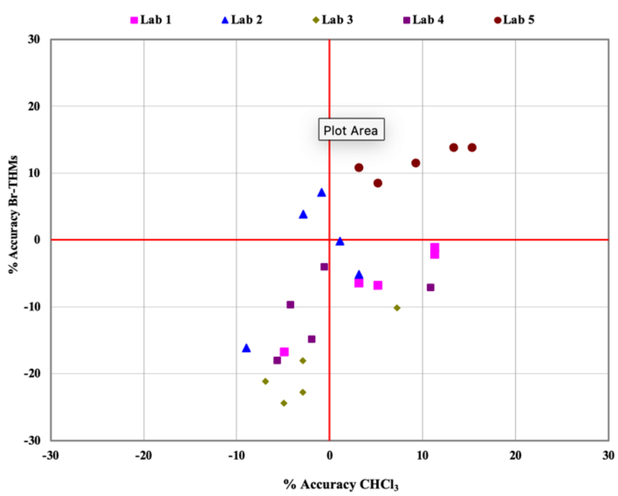

Figure 2- Accuracy Using Split Samples

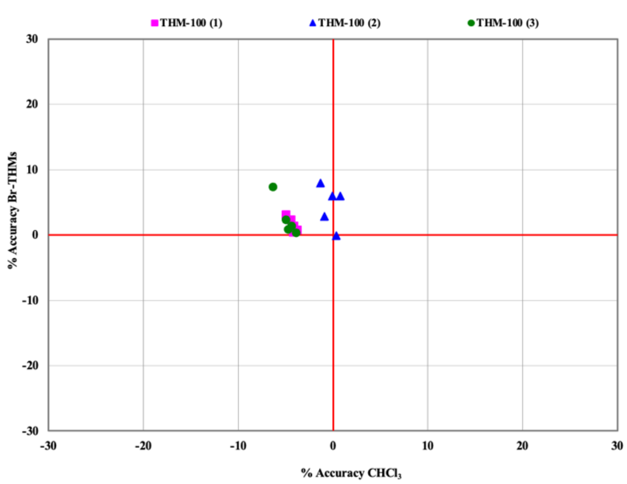

Figure 3- Accuracy Using Online THM-100™ Analyzer

TESTING

During the first six months of testing (October 2012 – March 2013), the Benicia WTP underwent individualized controlled testing for a variety of conditions with the goal of maintaining THM levels consistently under 40 ppb. The online analyzer provided accurate and timely information regarding THM formation in treated water. Daily THM results provided the operational staff with real-time feedback on the implication of process changes on THM levels in their finished water. As THM levels fluctuated, the operational staff would apply BMPs to adjust for an increase in THM levels.

Controlled test conditions included:

- Increase acidified alum to drive pH down to 6.3 – 6.5
- Reduce post disinfection to maintain TW Free Cl_2 Residual at 0.9 mg/L
- Reduce caustic soda feed to maintain RTW at a Saturation Index = 0.0

Following the initial six-month period, the Benicia WTP decided to extend the trial for an additional three months to enable the measurement of variations in THM formation during the change of source water from December through May.

Figure 4 depicts the THM levels based on source water changes. Heavy rainfall in December 2012 contributed to the high THM levels of the blended NBA and PSC source water.

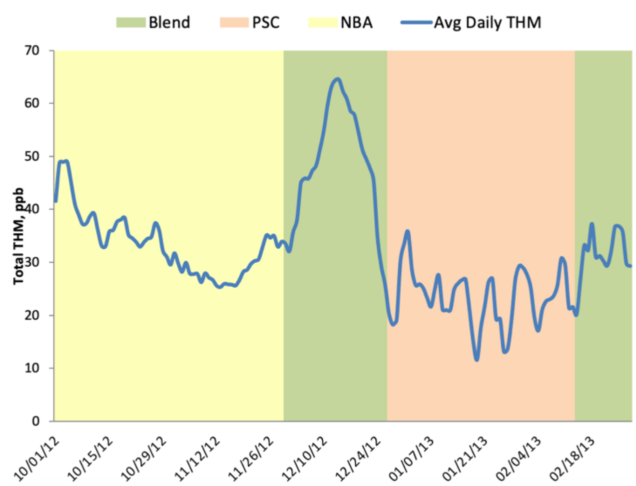

Figure 4- Benicia Source Water Changes and THM Levels

The extension of the trial also enabled the operations team to continue to measure THM fluctuations as they worked to optimize process controls and treatment schemes.

The Benicia WTP employs six GAC/sand dual media filters as part of their pre-treatment process. The dual media filters have a lower than normal loading rate of 3.6 gpm sq/ft, allowing for long filter runs of 80-100 hours that result in less backwash and recycled water to bring back to the plant. GAC media is replaced every six years for two filters at a time.

Figure 5 depicts the THM variations based on media age. The routine change out of GAC media for Filters #5 and #6 took place in December 2012. The accompanying graph in Figure 5 shows that when Filters #5 and #6 are in service, THM levels are lower in the finished water because of the higher adsorption capacity of the fresh GAC for removing dissolved organic carbon.

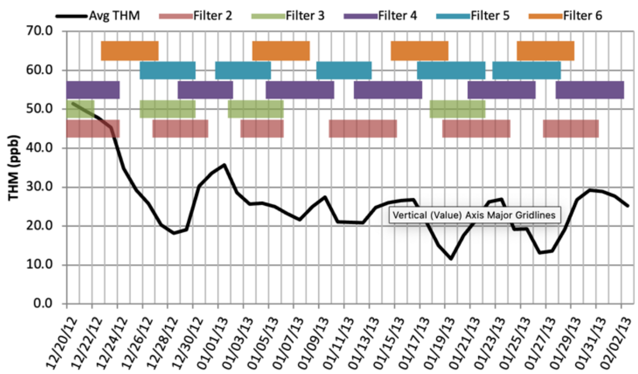

Figure 5- Average THM & GAC Filter Relationship

CONCLUSION

Since installing the online THM analyzer in October 2012, the staff at Benicia WTP has been able to accurately monitor the correlation between operating conditions and THM formation potential. Operators have been able to optimize plant performance and chemical dosage, allowing them to economize plant chemicals and dose pace accordingly.

Treatment anomalies have been detected early, enabling immediate correction to process controls. Daily THM values for Benicia WTP are depicted in Figure 6 and it is noticeable how quickly THM levels rose during the winter rains in mid-December 2012. The subsequent reduction in THM levels was due to the switch to Solano Project water in late December.

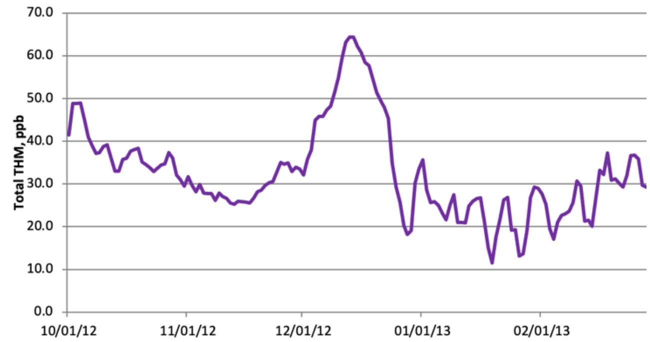

Figure 6- Benicia Water Treatment Plant Daily Average TTHM (PPB)

High levels of organic material will remain present in source water as the Benicia WTP works toward regulatory Stage 2 DBPR compliance. Continuous demonstration of THM formation due to source water and process conditions is made possible through the use of the online THM analyzer.

The integration of the online THM analyzer at Benicia WTP has become an essential element to avert regulatory breaches and deliver treated water of the highest quality to the City of Benicia.