

Stage 2 Disinfectants and Disinfection Byproducts Rule (DBPR) and Consecutive System In-Depth Analysis



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Executive Summary

The goal of an In-Depth Analysis is to identify compliance challenges related to a specific regulatory requirement and to share best practices for enhancing implementation. This national effort is strategic in scope, is conducted as a joint effort between the U.S. Environmental Protection Agency (EPA) and the states, and supports the EPA's breakthrough measure to reduce the number of community water systems (CWSs) with health-based violations by 25 percent within five years.

The EPA collaborated with the states to select areas for analysis, and state volunteers to participate in the effort. The EPA and the states work together to a) understand the root cause of the implementation issue; b) seek state best practices; and c) develop and provide targeted training and technical assistance to enhance the effectiveness of the Safe Drinking Water Act (SDWA) program.

The National Primary Drinking Water Regulation (NPDWR) with the largest number of CWSs in violation, roughly 30 percent of all violations during fiscal year 2017 and 2018, was the Stage 2 Disinfectants and Disinfection Byproduct Rule (DBPR). The **first chapter** of this report discusses the Stage 2 DBPR and Consecutive CWS Challenges. During this effort the EPA learned that more than half of the CWSs with a Stage 2 DBPR violation were consecutive systems, with a violation rate of 4.9 percent for consecutive CWSs compared to 1.4 percent for non-consecutive.

The **second chapter** discusses the national data analysis that was done to identify areas of the U.S. with Stage 2 DBPR compliance challenges and evaluate common characteristics of the CWSs that were out of compliance. As part of this analysis, the EPA looked at geographic distribution of Stage 2 DBPR health-based violation and found that these systems are located in a band from the mid-Atlantic states down through Texas, along with Alaska and Puerto Rico. The EPA also analyzed the maximum contaminant level (MCL) violations and found that:

- Total trihalomethanes (TTHM) MCL violations [systems with only TTHM or those with both TTHM and haloacetic acids (five) (HAA5)] were dominant comprising approximately 80 percent of the systems in violations;
- More than 70 percent of the violations occur at surface water systems; and
- Stage 2 DBPR violations occurred more frequently, and at higher concentrations above the MCL, for those systems serving 501 to 10,000 persons.

State best practices are provided in the **third chapter**. This information was based on site visits to the five partner states, as well as feedback from 32 other states provided by Association of State Drinking Water Administrators (ASDWA). The chapter is organized around the following key implementation challenges:

- 1. What approaches can a CWS take to reduce disinfection byproduct (DBP) formation?
- 2. What are the best practices for distribution system sampling and analytical methods?
- 3. What approaches can be used to facilitate coordination between a wholesale and consecutive system?
- 4. What capacity development tools can be used to address DBP issues?
- 5. How can Drinking Water State Revolving Fund (DWSRF) resources be used to assist systems with DBP violations?
- 6. How can state enforcement be used to help systems return to compliance?
- 7. What approaches can be used to enhance operator training on DBP compliance issues?

The *last chapter* provides approaches to reduce DBPs through optimization. This general approach was developed through pilot projects and field studies carried out by the EPA's Area Wide Optimization Program (AWOP).

The information provided in this report is intended to help state primacy agencies understand and address the compliance challenges related to the Stage 2 DBPR and consecutive systems, however it is important to recognize the limitation of the information provided in this report. The national data analysis presented in Chapter 2 represents a snapshot in time. The state implementation challenges and lessons learned provided in Chapter 3 may not be inclusive of all issues and approaches related to Stage 2 DBPR and consecutive systems. And finally, the system optimization approach provided in Chapter 4 shows one approach developed by EPA's AWOP program, however other approaches may also be effective.

Chapter 1: Stage 2 DBPR and Consecutive CWS Challenges

Why conduct a SDWA subject specific In-Depth Analysis?

A subject-specific In-Depth Analysis seeks to identify opportunities to improve the effectiveness of National Primary Drinking Water Regulation (NPDWR) implementation. This joint effort is conducted on a voluntary basis between the U.S. Environmental Protection Agency (EPA) and primacy agencies¹. With the understanding developed through this effort, the EPA will work with states to develop and provide targeted training and technical assistance to enhance the effectiveness of the Safe Drinking Water Act (SDWA) programs.



This effort supports the EPA's breakthrough measure to reduce the number of community water systems (CWSs) with health-based violations by 25 percent by 2022. Health-based violations include violations of maximum contaminant levels (MCLs), maximum residual disinfectant levels (MRDLs), and treatment technique (TT) rules.

Why focus on Stage 2 DBPR?

While health-based violations occur all over the U.S., in recent years the Stage 2 Disinfectant and Disinfection Byproduct Rule (DBPR) consistently makes up a substantial portion of the health-based violations (Figure 1). In fiscal year (FY) 2017, 1,188 of the approximately 50,000 CWSs in the U.S., had a Stage 2 DBPR health-based violation, comprising nearly 34 percent of all CWSs in violation. As Figure 2 shows, Stage 2 DBPR health-based violations were not only the most common violation in terms of both number of violations and CWSs in violation, they also impacted the second largest number of people. Furthermore, while the geographic distribution of all health-based violations (Figure 3a) illustrates a general distribution throughout the U.S., the CWSs with Stage 2 DBPR health-based violations (Figure 3b) are localized in specific regions; more details will be discussed in Chapter 2 For these reasons, the goal of this In-Depth Analysis is to understand the Stage 2 DBPR implementation challenges and share state best practices to improve compliance.



Figure 1: Proportions of CWSs with health-based violations in FY17 by rule. Some CWSs violated more than one rule and are therefore counted more than once.

¹ For the purpose of this report, primacy agencies are referred to as states.



Figure 2: Most common health-based violations at CWSs in FY17, plotting each rule by the population in violation versus the total number of violations for that rule, with the size of the circle representing the number of systems in violation. MCL violations are shown in green and TT violations are shown in yellow. As illustrated, Stage 2 DBPR has the largest total number of violations, the most CWSs in violation and the second largest population in violation.



Figure 3: Distribution of health-based violations at CWSs in FY17. Maps show a) locations of all CWSs with health-based violations, and b) locations of CWSs with Stage 2 DBPR health-based violations.

What are DBPs and how do they form?

Disinfection byproducts (DBPs) are formed when disinfectants used in water treatment react with natural organic matter (i.e., decaying vegetation) present in the source water or distribution system. DBP formation is influenced by several factors including:

- disinfectant type and dose,
- inorganic and organic precursor concentrations,
- pH,
- temperature, and
- water age.

The EPA has established NPDWRs in the Stage 1 DBPR and the Stage 2 DPBR for the following DBPs: total trihalomethanes (TTHM), haloacetic acids (five) (HAA5), bromate, and chlorite. Stage 1 DBPR also included a TT requirement for precursor removal (e.g., natural organic matter).

Why focus on consecutive CWS violations?

The EPA defines a consecutive CWS as a public water system (PWS) that receives some or all of its finished water from one or more wholesale systems.² The EPA recognizes that individual states may have a different definition for a consecutive CWS.

The Stage 2 DBPR can be challenging for consecutive CWSs to implement, as they have little control over the treatment processes of the water they receive, yet they must comply with MCLs for TTHM and HAA5. Further, the purchased finished water that a consecutive CWS receives may contain high levels of DBP precursors, or even high levels of DBPs. As such, water may meet the MCLs at the system interconnection, but concentrations may continue to increase in the consecutive systems distribution network.

The Stage 2 DBPR violation rate for consecutive CWSs is 3.5 times greater than non-consecutive CWSs.



Figure 4: Proportions of CWSs with health-based violations in 2017 by rule. Some CWSs violated more than one rule and are therefore counted more than once.

According to data pulled from the Safe Drinking Water Information System (SDWIS) Federal Reporting Service, nearly 27 percent of CWSs in the U.S. are at least partially consecutive (Figure 4). When all health-based rule violations are considered, the violation rates for non-consecutive and consecutive are similar. In contrast,

consecutive CWSs account for 56 percent of health-based Stage 2 DBPR violations that occurred in FY17. The Stage 2 DBPR health-based violation rate for consecutive community water systems is 3.5 times that observed for non-consecutive CWSs, 1.4 percent for non-consecutive compared to 4.9 percent for consecutive CWSs. As such, this In-Depth Analysis is further concentrating on Stage 2 DBPR violations at consecutive CWSs.

Seeking State Partners

At the March 2018 ASDWA Member Meeting, the EPA made a request for state partners to voluntarily participate in this In-Depth Analysis. Five states agreed to work with the EPA including: Indiana, Kentucky, New Jersey, North Dakota, and Pennsylvania. During the In-Depth Analysis, the EPA conducted a national data analysis of Stage 2 DBPR health-based violations (Chapter 2), conducted state site visits to evaluate compliance challenges and share lessons learned and best practices (Chapter 3), and worked with the Area Wide Optimization Program (AWOP) to identify strategies for Stage 2 DBPR compliance (Chapter 4).

The information provided in this report is intended to help state primacy agencies understand and address the compliance challenges related to the Stage 2 DBPR and consecutive systems, however it is important to recognize the limitation of the information provided in this report. The national data analysis presented in Chapter 2 represents a snapshot in time. The state implementation challenges and lessons learned provided in Chapter 3 may not be inclusive of all issues and approaches related to Stage 2 DBPR and consecutive systems. And finally, the system optimization approach provided in Chapter 4 shows one approach developed by EPA's AWOP program, however other approaches may also be effective.

What has been done previously on the issue?

The EPA has recognized the challenges related to Stage 2 DBPR compliance for consecutive CWSs since the rule was promulgated in 2006. The EPA has several guidance documents available to promote compliance with the Stage 2 DBPR requirements. Refer to the Additional Resources and References section for a list of publications at the end of this document.



Chapter 2: National Data Analysis of Stage 2 DBPR Compliance

What can we learn with SDWIS?

SDWIS contains information about PWSs and their violations of federal drinking water regulations, as reported to the EPA by the states. SDWIS is a valuable resource for answering the following questions related to Stage 2 DBPR and consecutive CWS challenges:

- How have Stage 2 DBPR violations changed over time?
- Are there geographic areas where Stage 2 DBPR MCL violations are more common? Is this pattern similar for consecutive CWS?
- How does source water type affect Stage 2 DBPR compliance?
- Are there noteworthy distinctions between HAA5 and TTHM violations?
- Which system sizes have the most Stage 2 DBPR MCL violations?

The SDWIS data from FY17 (October 2016 through September 2017) were used for this In-Depth Analysis because FY17 data were the most recent data available at the beginning of this project. A recent review of FY18 data shows a similar pattern to the FY17 data.

How have Stage 2 DBPR violations changed over time?

The Stage 2 DBPR monitoring and compliance requirements were phased in over several years as the rule took effect. As Figure 5 shows, the number of systems with Stage 2 DBPR health-based violations increased substantially from 2013 to 2016, as the Stage 2 DBPR requirements came to apply to all categories of CWSs.

To have a Stage 2 DBPR health-based violation (i.e., a TTHM or HAA5 MCL violation), a full year of monitoring is required; the previous four quarters for each sampling location are considered when calculating compliance. For example, the value for the fourth quarter (Q4) of FY15 includes sample results from the period from FY15 Q1 to FY15 Q4. Figure 5 indicates that the number of systems with Stage 2 DBPR health-based violations was highest in 2016 and has subsequently slowly decreased.



Figure 5: Number of CWSs with Stage 2 DBPR health-based violations from 2013 to 2018. The results for each calendar quarter represent the number of Stage 2 DBPR health-based violations that occurred during the previous year.

Are there geographic areas where Stage 2 DBPR MCL violations are more common?

Figure 6a shows how the number of CWSs in each state varies across the country. For example, Texas has 4,652 CWSs whereas Hawaii only has 116 CWSs. Figure 6b shows the number of CWS with Stage 2 DBPR health-based violations. Because of the variation in numbers of CWSs among states, it is helpful to normalize the occurrence of Stage 2 DBPR health-based violations by reporting them as percentages of CWSs (see Figure 6c) to identify more accurately the states that are challenged with Stage 2 DBPR compliance.



As Figure 6 shows, rates of Stage 2 DBPR health-based violations are not uniform across the states. Higher violation rates form a belt from the states of the south-central U.S. to the mid-Atlantic, with Oklahoma, Kentucky, and Louisiana having the highest violation rates. High violation rates were also found in Alaska and Puerto Rico.



Figure 6: Distribution of CWSs and Stage 2 DBPR health-based violations across the U.S. in FY17. Maps represent a) number of CWSs in each state; b) number of CWSs with Stage 2 DBPR health-based violations in each state; and c) percent of CWSs with Stage 2 DBPR health-based violations in each state. In addition to the violations represented there were three violations in the Navajo Nation, one violation in American Samoa, and four violations for CWSs in the EPA direct implementation program.

Are there geographic areas where consecutive CWSs Stage 2 DBPR MCL violations are more common?

Just as the number of all CWSs varies from state to state, so does the number of consecutive CWSs. Figure 7a shows for example, that Texas has 1,891 consecutive CWSs while Idaho only has 15. Figure 7b illustrates how the percentage of CWSs that are consecutive CWSs also varies. For example, over 70 percent of Kentucky's systems are consecutive CWSs, but only 2 percent of Idaho's systems are consecutive CWSs. Figure 7c shows the number of consecutive CWSs with Stage 2 DBPR health-based violations, and Figure 7d shows the percentage of consecutive CWSs with a Stage 2 DBPR health based violation. Although the rate of Stage 2 DBPR health-based violations is higher at consecutive CWSs than at all CWSs, the geographical distribution of violations is similar. Some states with larger proportions of consecutive CWSs, such as Oklahoma and Kentucky, are states where the highest rates of Stage 2 DBPR health-based violations occurred.



Figure 7: Distribution of consecutive CWSs and Stage 2 DBPR health-based violations across the U.S. in FY17. Maps represent a) number of consecutive CWSs in each state; b) percent of CWSs that are consecutive CWSs in each state; c) number of consecutive CWSs with Stage 2 DBPR health-based violations in each state; and d) percent of consecutive CWSs with Stage 2 DBPR health-based violations in each state. In addition to the violations represented, there was one violation each in the Navajo Nation and the EPA direct implementation program.

As shown in Chapter 1, the overall Stage 2 DBPR violation rate for non-consecutive CWSs is 1.4 percent, while the rate for consecutive CWSs is 4.9 percent. A common set of issues may be causing Stage 2 DBPR violations at all CWSs that is exacerbated for consecutive CWSs, including longer disinfected water residence times and the limited ability to control treatment processes that are managed by the wholesaler.

purchased

Surface water

Ground water

How does source water affect Stage 2 DBPR MCL compliance?

PWSs use one or more of three categories of source water: surface water, ground water under the direct influence of surface water, and ground water.

Surface water Based on SDWIS data, Stage 2 DBPR health-based violations occur primarily at CWSs that use surface water as the source water type (Figure 8). Overall, 70 percent of the violations occur at CWSs using surface water, regardless of producing their own water or purchasing from another system. However, a substantial number of violations, occur at CWSs using ground water, as well. This relationship is more pronounced when you look at only consecutive systems where approximately 81 percent had a surface water primar source, compared to approximately 18

percent for ground water. Violations for nonconsecutive systems were approximately 62 percent surface water, whereas 37 percent of violations were for ground water sources.

Unknown Primary Source

Ground water purchased

of surface water

Purchased ground water under influence of surface water

Groundwater under influence

Figure 8: Stage 2 DBPR health-based violations based on primary source water type used (FY17). Over 70 percent of the CWSs with Stage 2 DBPR health-based violations use surface water sources.



Figure 9: Frequency of Stage 2 DBPR MCL violation types at consecutive and non-consecutive CWSs (FY17). TTHM MCL violations (TTHM and TTHM/HAA5 MCL violations added together) account for more than 80 percent of the systems with Stage 2 DBPR health-based violations. This pattern is true for both consecutive and non-consecutive systems.

Are there distinctions between HAA5 and TTHM violations?

PWSs with Stage 2 DBPR health-based violations can have one of three types of violations: TTHM MCL violations, HAA5 MCL violations, or both TTHM and HAA5 MCL violations (TTHM/HAA5 MCL violations). When MCL violations are grouped into these three categories (Figure 9) it shows that TTHM MCL violations (systems with either a TTHM or TTHM/HAA5 MCL violations added together) account for more than 80 percent of the systems with Stage 2 DBPR health-based violations. This pattern is slightly more pronounced at consecutive (83 percent) than in non-consecutive CWS (76 percent). In contrast, systems with HAA5 MCL violations were overall much lower proportion of systems in violation than for TTHM (37 percent), with violations higher at non-consecutive CWSs (43 percent) than at consecutive CWSs (33 percent).

Which system sizes have the most Stage 2 DBPR health-based violations?

CWSs serving 501-3,300 people represent the system size category with the most Stage 2 DBPR health-based violations (Figure 10). This size category also has the highest percentage of consecutive CWSs in violation, at 6.3 percent. The size category with the highest percentage of all CWSs in violation is the category serving 3,301-10,000 people. At the time of the EPA's 2006 CWSs Survey, approximately 25 percent of all PWSs serving fewer than 500 people did not disinfect (USEPA, 2006). Systems that do not disinfect or use disinfected water do not need to comply with the Stage 2 DBPR, however this data has not been removed from the analysis provided in Figure 10. As such the data presented overestimates the number of small systems that need to comply with the Stage 2 DBPR and therefore the percentage violation data is higher.

The TTHM and HAA5 concentrations for those systems in violation exhibit a log-normal distribution without a clear distinction for consecutive CWSs or contaminant type (Figure 11 and Figure 12). The highest concentrations also appear to occur at both consecutive and non-consecutive systems that serve approximately 1,000 people.



Figure 10: Frequency of Stage 2 DBPR health-based violations at consecutive and non-consecutive CWSs of different system size category in FY17. Graphs represent a) the national inventory of CWSs and shows that most CWSs serve fewer than 500 people; b) illustrate that CWSs serving 501-3,300 people represent the system size category with the most Stage 2 DBPR health-based violations; and c) shows that this size category also has the highest percentage of consecutive CWSs in violation, 6.3 percent; for all the highest percentage was for those serving 3,301-10,000 people.



Figure 11: TTHM concentration versus the log of population size for CWSs with a TTHM MCL violation. The pattern is very similar for both consecutive and nonconsecutive CWSs, with highest concentration values above the MCL occurring at a population of roughly 1,000.



What about disinfection byproduct precursor removal (under Stage 1 DBPR)?

Disinfection byproduct precursor removal can be evaluated using total organic carbon (TOC) TT violations data from SDWIS. Please keep in mind that only conventional treatment systems are required to monitor for TOC removal whereas other systems, such as those using membrane filtration, do not need to meet this requirement. Sixty-three CWSs had TOC TT violations in FY17 and of those 27 CWSs (43 percent) had a simultaneous Stage 2 DBPR MCL violation. For CWSs with both a TOC TT and Stage 2 DBPR MCL violation, most of these systems (70 percent) are located in Oklahoma and Puerto Rico. However, even for those two states, only nine percent of systems with Stage 2 DBPR MCL violations also had simultaneous TOC TT violations. The number of simultaneous violations is therefore relatively low, however remember that not all systems that disinfect need to comply with the TOC TT requirement.

Chapter 3: Challenges, Lessons Learned, and Best Practices

Information on Stage 2 DBPR compliance challenges and best practices was gathered during site visits to the five partner states, in addition to feedback provided by ASDWA representing the combined input from 32 additional states.

The following Stage 2 DBPR questions are used to organize this chapter:

- 1. <u>What approaches can a CWS take to</u> <u>reduce DBP formation?</u>
- 2. What are the best practices for distribution sampling and analytical methods?
- 3. What approaches can be used to facilitate coordination between a wholesale and consecutive system?
- 4. What capacity development tools can be used to address DBP issues?

- 5. <u>How can Drinking Water State Revolving</u> <u>Fund (DWSRF) resources be used to</u> <u>assist systems with DBP violations?</u>
- 6. <u>How can state enforcement be used to</u> <u>help systems return to compliance?</u>
- 7. What approaches can be used to enhance operator training on DBP compliance issues?

What approaches can a CWS take to reduce DBP formation?

As described in SDWIS data analysis presented in Chapter 2, most Stage 2 DBPR compliance issues occur at CWSs using surface water sources. During the EPA's sites visits, the team observed that primarily CWSs disinfecting with chlorine are facing compliance challenges. Some consecutive systems purchasing finished water that was disinfected using chloramines have been assigned violations; however, there are multiple factors that may have contributed to these violations (e.g., supplemental

State Approaches

- Encourage wholesale systems to participate in operational evaluation reports triggered by their consecutive systems.
- Proactively work with systems to optimize both the distribution system and treatment plant processes for compliance.
- Coordinate with state enforcement programs to develop a path for a system to return to compliance.
- Provide operator training for representatives of systems that have had Stage 2 DBPR compliance challenges to share lessons learned with their peer group.

disinfection). There have also been Stage 2 DBPR MCL exceedances at CWSs using ground water, although based on sites visits these systems typically had extenuating challenges, such as areas of low demand resulting in high water age or poor source water quality.

During the state site visits, the EPA observed a variety of issues related to treatment plant and distribution system operations that contribute to TTHM and HAA5 MCL exceedances. Understanding the origin of Stage 2 DBPR problems is a critical step toward returning to compliance. For example, considering whether there have been any changes to the source or distribution system that may impact DBP formation since the initial distribution system evaluation (IDSE) was conducted. Other approaches a CWS can take to address DBP formation are listed below.

Use of Chloramines

Several states indicate that many of their systems have gained DBP compliance through chloramination (e.g., *Missouri, Indiana, South Dakota, and North Dakota*). Chloramination is an effective distribution residual strategy because it improves disinfection residual maintenance in distribution systems while addressing DBP compliance. Switching from free chlorine to chloramines is a significant change to a water systems treatment and a water system should insure that it has the necessary operational capacity to implement chloramination and the customers are prepared for the transition. There are also simultaneous compliance concerns with the use of chloramines, including nitrification in distribution systems. These can sometimes be addressed through routine maintenance activities such as flushing programs. The Stage 2 DBPR requires the state be notified and approve any significant treatment change, as determined by the state, prior to the PWS making the change.

Use of Pre-Chlorination

Due to limitations or constraints in treatment processes, some surface water systems are forced to pre-chlorinate to achieve adequate contact time (CT), before they have removed DBP precursors (measured as TOC), to meet Surface Water Treatment Rule (SWTR) requirements. Pre-chlorination before precursor removal has led to Stage 2 DBPR compliance issues in several states. A best practice is to review the need for pre-chlorination and to the extent practical to avoid or reduce pre-chlorination (e.g., move the point of pre-chlorination further down the treatment train). Profiling and benchmarking, as required in the suite of SWTRs, is one tool a water system may use to evaluate whether it would be possible to modify their treatment (i.e., point of pre-chlorination to reduce contact time of the disinfectant with precursors), which may help with DBP formation. Where pre-chlorination is necessary to achieve disinfectant CT, upgrades to the treatment plant, such as installing a post-treatment contact chamber to provide the necessary CT, may be an option for achieving compliance.

Precursor Removal

As discussed in the data analysis presented in Chapter 2, most water systems meet the Stage 1 DBPR TOC removal requirements in the treatment plant. There were examples of isolated events, such as algae blooms in reservoirs, where increased TOC in the raw water challenged TOC removal efficiency. Use of the Alternative Minimum TOC removal requirements varied by state [i.e., Step 2 – 40 CFR 141.135(b)(4)]. As a best practice, *Kentucky* is reviewing systems using Step 2 TOC removals to ensure the water systems are still optimized for TOC removal.



System Optimization

Water system optimization can be an effective tool to address DBP compliance challenges. *Kentucky* and *Pennsylvania* both use optimization programs to evaluate distribution system issues. Several programs exist to support water system optimization, including EPA's AWOP program and the American Water Works Association (AWWA)'s Partnership for Safe Water, and provide opportunities for water systems to improve their treatment performance. Kentucky uses the EPA sponsored AWOP approach to help guide their efforts which considers both distribution system and treatment plant issues. Kentucky has a state-required distribution system flushing program water systems use to address Stage 2 DBPR compliance issues. Pennsylvania uses the AWOP approach for the distribution system and has a separate filter plant performance evaluation (FPPE) that considers treatment plant optimization. The FPPE evaluates the effectiveness of a drinking water treatment plant in removing disease-causing organisms from the incoming raw water thorough an on-site survey of filter plant operations, equipment and water quality conditions. A more detailed discussion of the AWOP approach is provided in Chapter 4.

Long hydraulic residence times

Long distribution systems and/or large storage tanks also create challenges for water systems in some states where Stage 2 DBPR compliance issues develop in the distribution systems. As discussed in Chapter 2, this may be one of the reasons for the greater rate of violations for consecutive CWSs. Many options are available to reduce DBP formation in the distribution system related to water age management, reducing booster disinfection, and water main flushing program (USEPA, 2007b). Specific water age management strategies can include improving mixing and reducing water age in storage tank facilities, reducing water tank storage if not needed, and reducing artificial dead ends in distribution system. Use of autoflushers is one way to create artificial demand and is another way to reduce water age. Chapter 4 will discuss in more detail specific steps that can be taken to address distribution system DBP formation.

What are the best practices for distribution sampling and analytical methods?

In many states, distribution sampling locations were selected based on the results in the IDSE and have not been reviewed or updated. Sampling locations are typically only updated if there is a specific request from the system due to a change in sampling access. Analytical results are another challenge identified by several states. They described situations where sample results collected on either side of a system interconnection could yield results that may be above or below the MCL. The accuracy/recovery for gas chromatograph (GC) methods is +/- 20 percent for TTHM analysis and +/- 30 percent for HAA5 analysis. As a result, variability within this range could be expected.

Distribution System Evaluation

Sampling locations in the distribution system may need to change due to changes in demand, water system configuration, and storage or treatment (e.g., booster chlorination) within the distribution system. Most states review these changes on an as needed basis based on discussion with the system. Some states review these changes during sanitary surveys. In contrast, **Alabama** has a specific rule requirement to conduct a distribution system evaluation (DSE) every nine years, unless the system meets the 40/30 exemption or serves fewer than 500 customers (ADEM Administrative Code, 2017; r.335-7-2-.13). In addition, an updated DSE is required if any of the following conditions apply:

- 1. The system adds a new surface water or ground water under the influence of surface water source;
- 2. New treatment plant that does not have the same entry point as an existing water treatment plant;
- 3. The system adds a new well or spring that is not considered to be in the same aquifer as the existing water sources;
- 4. The system adds a new connection to another system that will be used more than 60 days out of the year;
- 5. The system consolidates with another system; or

6. The state requires the system to conduct another DSE.

DBP Analytical Methods

The EPA recommends the following best practices regarding TTHM and HAA5 analyses:

 In addition to the existing analytical methods (i.e., <u>502.2</u> or <u>551.1</u>), identified in the Stage 2 DBPR, the EPA has identified new and improved analytical methods (e.g., <u>552.3</u>, <u>524.3</u>, and <u>524.4</u>), which require multi-lab validation. These methods need to be adopted by the state in order to be used for compliance determination;

- 2. Ensure that samples are properly preserved and holding times are met (i.e., 14 days for TTHM and 28 days for HAA5);
- 3. Ensure that samples are collected at comparable times and analyzed using similar methods; and
- Review supporting data for quality assurance (QA) and quality control (QC) checks. QC should use a matrix spike and recovery should be +/- 30 percent.

What approaches can be used to facilitate coordination between a wholesale and consecutive system?

States typically have limited regulatory authority over contracts between wholesale and consecutive PWSs and these are typically related to the quantity of the water provided, rather than the quality. Contracts between wholesale and consecutive PWSs can last as long as 99 years, or may auto-renew, and last even longer. As a result, when the consecutive system has compliance issues with the NPDWRs, especially those related to Stage 2 DBPR, communication can become a challenge as the wholesale system may mention that they are meeting the requirements of the contract.

Consecutive PWS Purchase Agreements

is not subject to approval by the state.

While most states do not review purchase agreements, **Texas** does review them during sanitary surveys, and other states (e.g., **Wisconsin**, **Virginia**, and **Montana**), review them upon request. **Vermont** requires water allocation agreements and **Connecticut** requires a permit for the sale of excess water between wholesale and consecutive PWSs. **Minnesota** has an interconnection policy for CWSs and recommends submission of a Community Public Water System Interconnection Plan prior to entering into a purchase agreement (MDOH, 2019). **Michigan** reviews new agreements but does not have a formal approval process. Additional feedback on this topic was provided from the following states:



This ensures that monitoring requirements for the consecutive watersystem are appropriate.

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Purchase Agreements Addressing Water Quality



Our review did not identify any state requirement for a wholesaler purchase agreement to address water quality. However, inclusion of contract clauses or requirements that the wholesaler will provide water that meets federal and state standards is a best practice that occurs in many states (e.g., *Wisconsin, Virginia, Kansas, Montana, Hawaii, Louisiana, Alabama*, and *Iowa*). Some states also use their requirements for a system interconnection as an opportunity to evaluate water quality. Specific examples are detailed below:

Colorado—The Integrated Systems Rule [Section 11.42(4)] of the state's Primary Drinking Water Regulations allows wholesalers to assume responsibility for drinking water compliance for one or more regulatory requirements applicable to the consecutive PWS. As part of this rule, PWSs must apply for "integration". They must also include other required information

(e.g., distribution system maps, sampling plans, copy of the agreement between the interested parties). Colorado is required to review the submittal and either approve or deny the pplication. Minnesota–Under Minnesota Administrative Rule (4720.0040), Minnesota Department of Health must approve interconnection agreements between municipalities. Water quality issues are expected to be addressed in all interconnection plans, including water age, corrosion control, and communication plans that address problems as they occur.

lowa—Purchase agreements include the following phrase requiring potable water that meets the Code of Iowa requirements as well as the Iowa Administrative Code rules:

I am the authorized representative of the Owner of the water system identified above and state that the connection of the proposed water distribution system also identified above is approved by the owner, and that the owner accepts responsibility for providing potable water required by this project in accordance with the provisions of Chapter 455B, Code of lowa, and the rules of the Department of Natural Resources. This agreement shall not be construed in any way to affect any local ordinances, water service agreements, or fee systems entered into between the parties.

Joint Operation Evaluation Level Involvement

Some states have improved the value of the Operation Evaluation Level (OEL) by integrating the wholesale system into the evaluation process. A few states have developed specific state rule requirements to have wholesale systems conduct an OEL when it is triggered by their consecutive PWSs. In Alabama, if a consecutive PWS has a DBP (TTHM or HAA5) violation, regardless of the results at the interconnection. the wholesaler must participate in a joint OEL (ADEM Administrative Code, 2017; r.335-7-2-.16). Tennessee only requires the wholesale system's involvement when sampling at the interconnection is greater than 60 percent of the MCL; wholesale and consecutive PWSs must then jointly submit the required OEL report, including the steps to be implemented to eliminate future exceedances (TDEC, 2019; Chapter 0400-45-01-.36). Virginia requires a consecutive PWS to have its wholesaler complete the source and treatment sections of the OEL report

that is submitted to the state. In **New Jersey** when a consecutive system triggers an OEL, the state requires the consecutive system to complete a full OEL Report with their wholesale system. Other states did express that OELs can, however, serve as good conversation starter for discussions between consecutive and wholesale systems, and technical assistance providers, or state regulators.

Sampling at the Interconnection

While not required by the Stage 2 DBPR, sampling at the interconnection is a best practice that is recommended by many states. This practice informs the scope of the water quality problem when the consecutive system triggers an OEL or has an MCL violation. Some states require sampling at the wholesale and consecutive PWS interconnection, especially if triggered by consecutive PWSs' results as detailed below:

Tennessee-Requires

wholesalers and consecutive systems using water with either an MCL or OEL DBP exceedance, or any other systems designated by the state, to conduct quarterly monitoring for chlorine, pH, DBPs and other

water quality indicators as necessary. This sampling shall occur at or near the master meter having the highest annual arithmetic mean concentration for TTHMs or HAA5s with all systems reporting their test results to each other. Parent and consecutive systems shall coordinate sampling activities so that samples are collected on the same date or a date prescribed by the state. (TDEC, 2019; Chapter 0400-45-01-.36). North Dakota and Ohio–Require their wholesale systems to conduct special purpose sampling at the inter-connection when a sample exceeds or approaches the MCL in the consecutive PWS.

> Alabama–Wholesale systems (except systems with only ground water sources), as well as consecutive systems that sell to other consecutive systems, must submit the results of TTHM and HAA5 sampling at or near all points of delivery to consecutive systems (ADEM Administrative Code, 2017; r.335-7-2-.12).

Communication between Wholesale and Consecutive PWSs



States have found success when regular meetings are held between wholesalers and their consecutive PWSs to address Stage 2 DBPR compliance issues. **North Dakota** and *Indiana* indicated that getting wholesale and consecutive PWSs in the same room is a critical step towards identifying, and ultimately addressing, the root cause of the DBP issue. In their rule language, *Alabama* requires representatives from all systems involved to meet quarterly to evaluate the effectiveness of the measures implemented based on the joint OEL findings (ADEM Administrative Code, 2017; r.335-7-2-.16). Many states encourage and facilitate conversations between wholesalers and their consecutive PWSs, even when they are not required. When an OEL is triggered in *Iowa* or *Illinois*, consecutive PWSs and their wholesalers discuss possible source and treatment factors that could have elevated the results. State representatives get involved if needed. **Virginia** uses sanitary surveys as an opportunity to discuss cooperation between wholesale and consecutive PWSs and make recommendations to improve communication.

What capacity development tools can be used to address DBP issues?

Many PWSs with DBP compliance challenges often have TMF issues. Support for those PWSs through technical outreach and optimization programs was common and is generally found to be helpful in the states where it is provided; many states fund this through the capacity development set asides. *Missouri's* capacity development program prioritizes systems with elevated DBP concentrations for technical assistance under the EPA Training and Technical Assistance (T/TA) Grant. *Iowa* uses TA providers to implement tools such as maximizing removal of TOC, use of chlorine dioxide to remove additional organics, use of chloramines instead of free chlorine for distribution system residual, managing water age through flushing programs and managing elevated storage tanks, especially during hot weather.

Other states have used their set aside money to undertake special studies and map water distributions systems to address DBP issues. Examples include **Kansas** which is working with the EPA Region 7 to complete a special study sampling DBPs for consecutive PWSs and **New York** which has mapped water system boundaries for systems of concern and made this information available on state's Department of Health website. More detailed examples of other approaches are provided below:

Missouri-Has funded university researchers to perform a comprehensive study of the chemical characteristics of water for systems with DBP compliance challenges. Systems are selected after they have been determined to be open to findings of the report and willing to consider treatment plant process changes. Researchers consider coagulant types, feed rates, feed locations and how DBP concentrations are impacted throughout the plant and distribution system. These comprehensive studies have been carried out for approximately 20 PWSs, with about three per year being completed. The studies are helpful and identify numerous strategies PWSs can try such as: auto flushers; aerators in tanks; replumbing tanks; keeping tanks at a lower level; taking storage off line if it is not needed; making sure tanks are painted white, recalculating CT to make sure chlorine is not being overfed; and covering basins to reduce chlorine demand.

Texas—Has provided technical assistance by sending Texas Optimization Program staff to wholesale and consecutive PWSs to approach their issues with a holistic view. Assistance typically involves a review and analysis of historical data to identify any trends, an on-site review of the treatment process, additional sampling outside of compliance schedules for process control information, and additional specialized studies based on the specific needs and demands of the system receiving the assistance. Vermont-Has a parttime staff member providing direct technical assistance to PWS with water quality issues. This often includes DBP formation and removal of DBP precursors. Through this position, the state has been able to monitor ultraviolet (UV) absorbance at certain PWSs and implement management initiatives. For example, this review may suggest operationally changing how the system receives incoming raw water, for example only drawing from a stream at night during spring snowmelt or diverting from a fast-moving stream instead of pulling from a reservoir.

How can DWSRF resources be used to assist systems with DBP violations?

For some PWSs, capital improvements may be necessary to address the root cause of the DBP issue. Connecting these systems with the DWSRF can assist them to return to compliance. As part of the ranking criteria many states use heath-based violations as a scoring mechanism to prioritize funding. The DWSRF program has recently developed two fact sheets highlighting eligible activities and specific projects that have been funded in the past to address DBP violations (USEPA, 2019a; USEPA, 2019b). A few DWSRF specific programs elements related to Stage 2 DBPR are detailed below:

Oklahoma-Is in the process of using 20 percent of the DWSRF Grant as its mandated subsidy to provide \$100,000 loans that are forgiven to address Stage 2 DBPR issues. The state is using other funds to contract with a bond attorney for these small forgiven loans to keep costs down. The state is also creating a pre-qualification list of engineers experienced in DBP treatment. PWSs will select an engineer from this list unless they already have an engineer under contract. Oklahoma Department of Environmental Quality (ODEQ) will meet with the wholesale system along with its consecutive PWSs to update sample site plans and see

if purchased water is in compliance as it enters the consecutive PWS. ODEQ will give the \$100,000 subsidy as its first priority to the wholesale system to see if the DBP issue can be resolved for both the wholesale system and its consecutive PWSs. They anticipate this program will start obligating money during the spring of 2019.

Wisconsin–Has incentivized asset management by giving principal forgiveness points for approved plans (Wisconsin Department of Natural Resources, 2019). Plans must include infrastructure inventories (including maps) that provide pipe length, age, diameter, condition, and location, as well as valve and hydrant location and age. These maps can be used to determine problem areas for Stage 2 DBPR compliance.

How can state enforcement be used to help systems return to compliance?

Systems with historical significant compliance issues benefit from a proactive enforcement program that provides a path toward compliance. Typically, these systems require substantial assistance from their states and technical assistance providers. For example, *Kentucky's* enforcement program works closely with the drinking water program staff to develop enforcement orders that seek to identify and address the root cause of the issue. Typically, this involves using the approaches adopted by the state's optimization program to develop a path to compliance. In states with a small number of Stage 2 DBPR violations these are typically handled on a case-by-case basis due to the low frequency of TTHM and HAA5 MCL violations. Other states provided additional proactive enforcement examples are provided in the following graphic.

Montana-Had a PWS voluntarily

enter into an Administrative Order on Consent (AOC) that included a work plan and deadlines to resolve the problem. This provided the PWS with the time needed to make changes without incurring additional violations.

Colorado-Has found that close collaboration between the regulating agency and the PWS can lead to short-term solutions that immediately

workgroup that evaluates DBP compliance trends and works with systems

protect public health (e.g., flushing programs, improved tank storage), while long-term solutions are being designed and funded (e.g., improved treatment processes for TOC removal and chlorination). They also indicated that intra-departmental collaboration on DBP enforcement cases is critical, coupled with the willingness to work with the PWS on acceptable DBP treatment methods. This can help protect public health and resolve DBP-related challenges often with timely and low-cost solutions.

North Carolina–Approximately two years ago, developed a new and still evolving MCL enforcement process that has focused primarily on DBPs, as these systems often fail to meet Administrative Order (AO) deadlines. The biggest change has been an enforcement process escalation protocol for unresolved MCLs.

> Oklahoma-Issued 140 consent orders from 2016 to 2017 to address DBP exceedances. The consent orders have a schedule for returning to compliance. These PWSs are in the process of completing tasks that include an operational corrective action plan, engineering report, plans and specifications, construction, and monitoring.

What approaches can be used to enhance operator training on DBP compliance issues?

Providing operator training from those who have experienced Stage 2 DBPR compliance issues has proven to be a successful approach. A few examples are provided below.

North Dakota–At their annual state conference, North	
Dakota organizes a panel of operators from small, medium,	
and large systems who have	Missouri–In 2017, the state provided one-
dealt with common challenges.	day training courses that focused on how
These panelists present their	to reduce DBPs at nine different locations
approaches to dealing with the	in the state. Compliance data were used to
identified DBP problems. This peer	target the locations of the courses, which
training helps put the challenge in	wer <mark>e fund</mark> ed through the EPA's T/TA Grant.
the operator's language and	
knowledge framework.	
-	
Colorado–Has a training	

that have exceeded or are approaching compliance limits. The workgroup has developed DBP training material to help these systems evaluate their water quality and find potential source, treatment, and distribution solutions. Colorado has had tremendous success working with systems one-on-one and has been able to help a handful of systems return to compliance by making operational changes. Small system operators have been educated on various solutions and their relative costs so the systems are in a better position to work with their engineers if new treatment and/or infrastructure are needed. Additionally, Colorado has partnered with the local American Water Works Association (AWWA) section to provide classroom-style DBP training.

Chapter 4: Approaches to Reduce DBPs through Optimization

Detailed below is a general approach to reduce DBPs that has been developed through pilot projects and field studies carried out by the EPA Office of Ground Water and Drinking Water's Area Wide Optimization Program (AWOP). AWOP formalizes these activities and encourages states to implement optimization concepts. The program also provides a network of participating states that can collaborate on optimization activities and on the implementation of elements of their state drinking water programs. Involvement with AWOP can enhance a state's ability to provide technical assistance to PWSs that are challenged with DBPs. Presently 29 states are active or limited AWOP participants, and about half of these are using it for DBP optimization. States and PWSs that are not formally involved with AWOP can still successfully implement these concepts. Additional information about AWOP can be found in the references section of this document (USEPA, 2019c).

What is the AWOP DBP optimization approach?

The overall AWOP DBP approach, shown in Figure 13, includes both treatment plant optimization (shown on the left) and distribution system optimization (shown on the right). It is important to recognize that some PWSs need to work on both treatment plant and distribution system optimization to achieve compliance or their treatment goals.

For Stage 2 DBPR issues, treatment plant and distribution system optimization may both be effective for TTHM reduction in CWSs and non-transient non-community water system (NTNCWSs) that disinfect with chlorine. However, CWSs and NTNCWSs disinfecting with chloramines may also optimize their treatment to lower DBP formation prior to adding ammonia and manage water age to provide better disinfectant residual maintenance. Typically, HAA5 may only be reduced through treatment plant optimization. If a PWS has already pursued DBP operation practices (e.g., stopped prechlorination, enhanced TOC removal, minimized water age in the distribution system), they may not have the potential to reduce DBPs. Under such circumstances, experience with optimization efforts and associated data will support the process of identifying and implementing any capital improvements.

AWOP teaches skills to improve water system operations, rather than focusing on costly capital improvements.



Figure 13: Frequency of Stage 2 DBPR MCL violation types at consecutive and non-consecutive CWSs (FY17). TTHM MCL violations (TTHM and TTHM/HAA5 MCL violations added together) account for more than 80 percent of the systems with Stage 2 DBPR health-based violations. This pattern is true for both consecutive and non-consecutive systems.

How do you diagnose DBP formation and water quality stability?

This first step of the optimization process involves diagnostic monitoring and conducting a plant effluent hold study.

The goal of diagnostic monitoring is to identify if DBPs are predominantly forming in the treatment plant, in the distribution system or in both places (Figure 14). Monitoring is conducted at the entry point to the distribution system (i.e., the treatment plant effluent), at consecutive PWS interconnections

and at distribution system locations where maximum DBP concentrations have been found (e.g., at the Stage 2 DBPR maximum residence time location).

Additionally, a hold study can also be performed to assess the reactivity of the water (i.e., water quality stability). Treatment plant effluent samples are collected and held for a period of time before they are analyzed to measure disinfectant decay and/or DBP formation. If the water is very reactive, additional treatment may be needed. Hold studies do not assess pipe wall reactions.

Results of both studies are used to prioritize efforts and identify whether to first focus on the treatment plant or the distribution system. Often, both treatment plant and distribution system can benefit from optimization efforts.

A hold study is a useful tool when determining if the system should focus on DBP control strategies at the plant or within the distribution system. A hold study can help water systems identify if chlorine degradation issues are from distribution system deficiencies.



Figure 14: A schematic diagram of a conventional treatment plant.

What can be controlled in the treatment plant?

Evaluating how a treatment plant is being operated can reveal additional ways DBPs and their precursors may be reduced (Figure 15). Key operational treatment changes that can impact DBP formation include optimizing preoxidation and improving DBP precursor removal.

Optimizing preoxidation strategy to eliminate prechlorination (if applicable) and utilize an effective oxidant/ dose. Note that prechlorination is defined as chlorine addition prior to TOC removal, which generally occurs through the coagulation/flocculation/sedimentation process. Many systems require some type of preoxidation (e.g., permanganate, chlorine dioxide, other) to meet their overall water quality objectives, and this should be maintained/enhanced. If pre-chlorination is eliminated, the PWS must ensure there is enough intermediate disinfection to maintain disinfection CT and provide sufficient treatment plant effluent residual. Improving DBP precursor removal by reducing finished water TOC can be accomplished through optimized coagulation. PWSs that use surface water or ground water under the direct influence of surface water and conventional filtration treatment are required under the Stage 1 DBPR to remove specified percentages of organic materials (measured as TOC) that may react with disinfectants to form DBPs. Some systems are able to achieve additional TOC removal, which will likely result in lower DBP formation. Additional, or optimized, TOC removal is generally achieved through some combination of changing coagulant dose or pH, and/or utilizing an alternate coagulant.

Treatment-based strategies for controlling DBPs are prioritized by conducting disinfection benchmarking and profiling for the plant, as required under the SWTR, conducting a plant profile (i.e., sampling disinfectant, pH, temperature, TOC, UV254, and DBPs), and analyzing historical water quality (i.e., reviewing raw and finished water TOC, coagulant dose and pH, disinfectant dose and residual). Secondary impacts of each DBP control strategy must be considered to prevent unintended consequences or simultaneous compliance issues, especially related to the SWTR and the Lead and Copper Rule (LCR). For example, optimizing the use of oxidants and/or disinfectants for DBP control might:

- Lower disinfection CT and/or distribution system disinfectant residual;
- Reduce the treatment plant's ability to meet inorganic oxidation demands (e.g., iron or manganese oxidation and removal goals);

- Change finished water pH which could impact corrosion control optimization under the LCR;
- Impact treatment strategies for harmful algal blooms; and/or
- Allow for increased in-plant biogrowth.

Optimizing DBP precursor removal might:

- Require additional corrosion control due to a change in coagulation chemistry;
- Change the quantity and/or quality of the treatment sludge; and/or
- Reduce manganese removal due to lower coagulation pH.



Figure 15: Common approaches to reduce DBP formation include optimizing preoxidation strategy by reducing or eliminating pre-chlorination (shown in red) and increasing precursor removal in the treatment process (shown in green); often a combination of both strategies is necessary.

What can be controlled in the distribution system?

Distribution system optimization strategies for controlling DBPs are primarily related to reducing water age. These strategies can be utilized by a parent or consecutive PWSs. As with the treatmentbased strategies, unintended consequences associated with distribution system optimization must be considered. DBP control strategies can be prioritized through investigative sampling (primarily disinfectant residual) to identify critical locations, assessing storage tank performance and water quality, and conducting additional water quality monitoring in and around tanks. Some strategies include modifying storage tank operations, distribution system flushing program, and modifying distribution system hydraulics. Minor distribution system design changes or treatment (e.g., installation of a mixing or THM aeration system) may also be an effective strategy.

If DBP issues are localized following a water storage tank (Figure 16) it would be appropriate to evaluate the tanks operations and maintenance. General approaches can include modify tank levels, change fill rate and/or duration, remove tank(s) from service, and ensure that tank maintenance is adequate.



A distribution system flushing program (Figure 17) can have several objectives with different impacts on water quality depending on the type of program a system implements. For example, automatic flushing is intended to create "artificial demand" and reduce water age in the distribution system by strategically flushing older, stagnant water on a periodic basis, whereas unidirectional flushing intends to scour lines and potentially reduce chlorine demand and DBP precursors, typically on an annual basis. Modest flushed water volumes can suffice to replace stagnant water with higher quality water to minimize DBP formation and maintain chlorine residual. Figure 16: A water storage tank.

Changing how water moves through a distribution system can also be an effective approach to reduce hydraulic retention times and minimize DBP formation. Modifying system hydraulics is a particularly effective strategy for systems that can reroute flow through a low demand area to an area of higher demand (i.e., areas with parallel lines and/or operational flexibility).

Existing treatment in the distribution system can sometimes be improved for DBP control,

for example, booster disinfection that is already in place can be optimized. At times, however, treatment modifications are needed and capital improvements that focus on impacting distribution system water quality may be warranted.

The highest priority strategy should be implemented, being mindful of unintended consequences or secondary impacts, which might include (but are not limited to):

- reduced capacity for peak demands;

low water pressure due

to reduced tank levels;

- potential hydraulic challenges associated with rerouting water and pumping changes; and
- political or consumer concerns (i.e., from taking tanks out of service, related to flushing and water conservation concerns, dirty water complaints).



Figure 17: Distribution system autoflusher

Additional Resources and References

Additional Resources

Stage 2 DBPR Implementation Guidance

This EPA guidance (USEPA, 2007a) for the EPA Regions and states explains how the EPA interprets the Stage 2 DBPR and provides guidance to the public and the regulated community on implementing the statute and regulations.

Stage 2 DBPR Consecutive Systems Guidance Manual

This EPA guidance (USEPA, 2010) is intended specifically to help consecutive CWSs understand and meet the requirements of the Stage 2 DBPR.

- <u>Simultaneous Compliance Guidance Manual for the Long Term 2 and Stage 2 DBP Rules</u> This EPA guidance (USEPA, 2007c) discusses the issues systems may face as they evaluate and implement changes necessary to comply with the Microbial and Disinfection Byproduct (M-DBP) Rules; specifically, Chapter 4 of this document focuses on potential Lead and Copper Rule compliance issues.
- <u>Stage 2 Disinfectant and Disinfection Products Rule: Operational Evaluation Guidance Manual</u> This EPA guidance manual guidance provides technical information on completing an operational evaluation as required by the Stage 2 DBPR.
- Evaluation of Disinfection Practices for DBPs and Precursor Occurrence in Consecutive Systems
 This Water Research Foundation paper (Chowdhury et al., 2008), co-sponsored by the EPA, characterizes
 DBPs and DBP precursor occurrence in consecutive CWSs that acquire treated water from a largersystem wholesaler and provides suggestions regarding how to identify acceptable DBP level goals
 for consecutive CWS entry points, strategies for consecutive CWSs to reduce DBP concentrations, and
 recommendations for negotiations between consecutive CWSs and wholesalers. http://www.waterrf.org/
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Acronyms

AOC	Administrative Order on Consent
AO's	Administrative Orders
ASDWA	Association of State Drinking Water Administrators
AWOP	Area Wide Optimization Program
AWWA	American Water Works Association
СТ	Product of disinfectant concentration (C) and contact time (T)
CWS	Community Water System
DBPR	Stage 2 Disinfectant and Disinfection Byproduct Rule
DBP	Disinfection byproduct
DS	Distribution System
DSE	Distribution System Evaluation
EFC	Environmental Finance Center
EPA	U.S. Environmental Protection Agency
ETT	Enforcement Targeting Tool
FY	Fiscal Year
GC	Gas Chromatograph
GWR	Ground Water Rule
HAA5	Haloacetic Acids (Five)
HRL	Health Reference Level
IDSE	Initial Distribution System Evaluation
IOC	Inorganic chemicals, including arsenic
LCR	Lead and Copper Rule
LRAA	Locational Running Annual Average
LT2ESWTR	Long Term 2 Enhanced Surface Water Treatment Rule
MCL	Maximum Contaminant Level
MRDL	Maximum Residual Disinfectant Level
NO3	Nitrate Rule
NPDWR	National Primary Drinking Water Regulation
NTNCWS	Non-Transient Non-Community Water Systems
OELs	Operational Evaluation Levels
ppb	Parts Per Billion
ppm	Parts Per Million
PWS	Public Water System
Rads	Radionuclides Rule
RTCR	Revised Total Coliform Rule
SDWA	Safe Drinking Water Act
SDWIS	Safe Drinking Water Information System
Stage 1 DBPR	Stage 1 Disinfections and Disinfection Byproducts Rule
Stage 2 DBPR	Stage 2 Disinfections and Disinfection Byproducts Rule
SWTR	Surface Water Treatment Rules
T/TA	EPA Training and Technical Assistance
TMF	Technical, Managerial, and Financial
TNCWS	Transient Non-Community Water System
TOC	Total Organic Carbon
TT	Treatment Technique
TTHM	Total Trihalomethanes
UV	Ultraviolet