Water and Wastewater Regulatory Compliance Corner
Stage 1 Disinfectants and Disinfection Byproducts Rule
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Background

Drinking Water Regulation in America

The Safe Drinking Water Act (SDWA) was originally passed by Congress in 1974 to protect public health by regulating the nation's public drinking water supply. The law was amended in 1986 and 1996 and requires many actions to protect drinking water and its sources—rivers, lakes, reservoirs, springs, and ground water wells.

SDWA authorizes the United States Environmental Protection Agency (EPA) to set national health-based standards for drinking water to protect against both naturally occurring and synthetic contaminants that may be found in drinking water. EPA, Tribal Nations, states, and water systems then work together to make sure that these standards are met.

Introduction to Regulation

To protect customers, the EPA has issued specific regulations and rules that water utility systems must follow to make sure they are providing safe drinking water. The EPA issued the Stage 1 Disinfectants and Disinfection Byproducts Rule (Stage 1 DBPR) in 1998 that requires water systems to monitor the water they provide to customers for any potential harmful by-products of the disinfection process. The EPA has also released the Stage 2 Disinfection Byproducts Rule published in 2006 (Stage 2 DBPR); see the companion Regulatory Corner for a comprehensive understanding of the DBPR.

Terms to Know

Acute health effect: Effect that develops immediately or within a short time frame (i.e., a single glass of water).

Conventional filtration: Conventional treatment removes particulate matter from water by forcing the water to pass through porous media. The filtration system consists of filters with varying sizes of pores, and is often made up of sand, gravel, and charcoal.

Chronic health effect: Longer periods of exposure such as a single glass of water each day for decades are believed to be linked to a cancer risk for consumers. Thus, regulations surrounding DBPs are aimed at reducing the repeated exposure over time and is thus evaluated on an average basis over time.

Community Water System: A public water system that supplies water to the same population year-round.

Disinfection Byproduct (DBP): DBPs form when water containing organic substances is disinfected. In most cases, the organic substances are naturally occurring, such as humic and fulvic acids resulting from decaying vegetation. A group of chlorinated organic compounds called THMs was one of the first products of the reaction of chlorine with humic substances to be recognized. The principal THMs of concern are chloroform, bromodichloromethane, chlorodibromomethane, and bromoform.

Disinfection Byproduct (DBP) Precursor: Precursors for DBPs are carbon molecules that are in the source water. These are present to form DBPs. Often, spring rainfall will drive runoff (humic and fulvic acids) into the source water which increases the number of DBPs formed. Total Organic Carbon (TOC) is a method used to measure the number of DBPs coming into the water treatment plant and can be used to assist operators in adjusting their systems to reduce the formation of DBPs. Some systems are upgraded with pretreatment chemical addition that does not use chlorine substituting in chemicals such as ozone or chlorine dioxide to avert the formation of DBPs.

Haloacetic acids (HAA5): The sum of five specific haloacetic acids, which are mono-, di-, and trichloroacetic acids plus mono- and dibromoacetic acids.

Humic Acid: Humic acids are fully decomposed remains of organic life; refers to a complex mixture of many different acids. They exist naturally as part of nature's life cycle in soils, oceans, and streams.

Locational Running Annual Average (LRAA): A value calculated by separately averaging the four quarterly samples at each monitoring location. If there are four locations, there will be four LRAA values.

Maximum Contaminant Level (MCL): The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to MCLGs as feasible using the best available treatment technology and taking cost into consideration. MCLs are enforceable standards.

Maximum Contaminant Level Goal (MCLG): The level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety and are non-enforceable public health goals.

Maximum Residual Disinfectant Level (MRDL): The highest level of a disinfectant allowed in drinking water. Addition of a disinfectant is necessary for control of microbial contaminants. For instance, cholera is an acute diarrheal infection caused by ingestion of food or water contaminated with the bacterium Vibrio cholerae. Researchers have estimated that each year there are 1.3 to 4.0 million cases of cholera, and 21,000 to 43,000 deaths worldwide. Disinfection of water systems is critical to protect Tribal Nation public health.

Maximum Residual Disinfectant Level Goal (MRDLG): The level of a drinking water disinfectant below which there is no known or expected risk to health. MRDLGs do not reflect the benefits of the use of disinfectants to control microbial contaminants.

Natural Organic Matter (NOM): Natural organic matter (NOM) in source water is a complex mixture of many carbon-based compounds that result from the breakdown/decay of plant and animal tissue (humic and fulvic acids).

Non-Transient, Non-Community Water: A public water system that regularly supplies water to at least 25 of the same people at least six months per year. Som examples are schools, factories, office buildings and hospitals which have their own water systems.

Residual Disinfectant: The amount of disinfectant in the distribution system, after water has left the treatment facility.

Running Annual Average (RAA): The running annual average is the average of the LRAA values collected in a sampling system. If there are 4 monitoring locations, the RAA will be the average of the 4 LRAA values. DBP compliance values are based solely on the RAA, not a single quarterly result at any-one monitoring location.

Specific Ultraviolet Absorption (SUVA): An indicator of the organic content of water. It is a calculated parameter obtained by dividing a sample's ultraviolet absorption at a wavelength of 254 nm (UV 254) by its concentration of dissolved organic carbon (DOC) (in mg/L).

Subpart H systems: Public water systems using surface water or ground water under the direct influence of surface water (via mixing) as a source.

Trihalomethanes (THMs): Disinfection by-product compounds formed by the reaction of organic material (humic and fulvic acids) in water with chlorine or other disinfectants, consisting of chloroform, dichlorobromomethane, bromodichloromethane, and bromoform. THMs are regulated as a group, with a MCL established for total THMs (TTHM).

Total Organic Carbon (TOC): Number of organic compounds contained in a sample of water. This is directly influenced by the NOM present in source water.

Overview

The Stage 1 DBPR was designed to reduce the levels of disinfection byproducts in drinking water supplies. The Stage 1 DBPR established:

- Maximum residual disinfectant level goals (MRDLGs) for: chlorine; chloramines; and chlorine dioxide.
- Maximum contaminant level goals (MCLGs) for:
  - Four TTHMs: Chloroform; Dichlorobromomethane; Bromodichloromethane; and Bromoform.
  - Five HAA (commonly referred to as HAA5): Monochloroacetic acid; Dichloroacetic acid; Trichloroacetic acid; Monobromoacetic acid; and Dibromoacetic acid.
- Bromate, an ozone (O_3) byproduct.
- Chlorite, a chlorine dioxide (ClO_2) byproduct monitoring, reporting, and public notification requirements for these compounds.

The Stage 1 DBPR applies to public water systems that are community water systems (CWSs) and non-transient non-community water systems (NTNCWSs) that treat water with a chemical disinfectant (such as chlorine) for either primary (pretreatment system) or residual treatment.

The Stage 1 DBPR provides public health protection for households that were not previously covered by drinking water rules for disinfection byproducts. The rule adds coverage for CWSs and NTNCWSs serving **fewer** than 10,000 persons. In addition, the rule, for the first time, provides public health protection from exposure to HAAs, chlorite and bromate.

Where Do Disinfection By-Products Come From?

Disinfection is a requirement in drinking water treatment that is enforced to protect public health. The choice of disinfectant can react with organic and inorganic material in source water to form DBPs. These organics come from organic debris in the water such as leaves and other natural organic matter (NOM) or debris.

The formation of DBPs is usually a greater concern for water systems that use surface water, such as rivers, lakes, and streams, as their source. Surface water sources are influenced by the addition of organic materials particularly during spring runoff and fall rain seasons. These humic materials combine with chlorine to form DBPs. Groundwater systems are not influenced by these additional materials because the natural flow of water into the aquifer filters out these materials. Sometimes blending surface water source water with groundwater is a mechanism used by Tribal Nations to keep DBPs within the SDWA standard.

Monitoring Levels

MEASURING DISINFECTANTS

The EPA established maximum residual disinfectant level goals (MRDLGs) and MRDLs for three chemical disinfectants (chlorine, chloramine, and chlorine dioxide) to assist in averting the formation of DBPs in the water distribution system.

Regulated Disinfectants	MRDL (mg/L)	MRDLG (mg/L)
Chlorine	4.0	4
Chloramines	4.0	4
Chlorine Dioxide	0.8	0.8
MRDLs and MRDLGs are for disinfectants only.		

MEASURING DBPS

Scientists have identified hundreds of DBPs. Several types of DBPs have limits set by the EPA: trihalomethanes (TTHMs), haloacetic acids (HAA5s), chlorite, and bromate.

DBP	MCL (mg/L)	MCLG (mg/L)
TTHMs	0.080 (sum of regulated TTHMs). Or some report as 80 µg/L.	Three individual MCLGs were established: Bromodichloromethane at Zero Dibromochloromethane at 0.06 Bromoform at Zero
HAA5	0.060 (sum of regulated HAA5), Or some report as 60 µg/L.	Two individual MCLGs were established: Dichloroacetic acid at Zero Trichloroacetic acid at 0.3
Chlorite	1.0	0.8
Bromate	0.010	0
MCLs and MCLGs are for disinfection by-products only.		

EPA set these limits by balancing the health benefits of water disinfection with the risk of exposure to disinfection byproducts. All public water systems that disinfect must regularly test their treated water to determine if regulated DBPs are present and at what levels. If they are above the limits set by EPA, the water system must take action to reduce the DBPs. Actions could include adjustments to:

- organics removal processes
- disinfection dose and location
- distribution system management

The water system must also notify all their customers of the DBP levels in their Consumer Confidence Report annually by reporting the total TTHM and total HAA5 numbers.

COMPLIANCE FOR DBPS

Under Stage 1 DBP Rule, the compliance value for TTHM and HAA5 is determined by calculating a running annual average (RAA) during the previous 12 months for each DBP for all monitoring locations. **Compliance is based solely on the RAA, not a single quarterly result at any-one monitoring location.**

How to calculate and RAA (with randomized values)						
Year	Quarter	Sampling Location A	Sampling Location B	Sampling Location C	Sampling Location D	Description
1	3	34	56	79	79	These values are the actual levels sampled at each location for DBPs
1	4	46	93	19	62	
2	1	11	14	89	17	
2	2	16	81	71	77	
LRAA		26.75	61	64.5	58.75	These numbers are the averages of samples at each sampling location
RAA		$\frac{26.75+61+64.5+58.75}{4} = \mathbf{52.75}$				This value is the average of the LRAAs

MONITORING REQUIREMENTS

Representative sampling allows systems to collect samples from the sources that represent (serve) the monitoring site rather than from all sources. The other locations must be far enough away from the plant entry points to be representative of the average residence time in the distribution system.

For an average rule of thumb when selecting sampling locations:

- TTHM location = Oldest water age
- HAA5 location = Average water age, unless a small system

DBP	Location for Sampling – must be representative of the distribution system with one location at maximum residence time	Small Surface Water System – must be representative of maximum residence time in the distribution system	Small Ground Water Systems
TTHM and HAA5	Locations representing maximum residence time *	1 per plant per quarter	1 per plant per year
Bromate	Distribution System entrance point	1 per month per treatment plant using ozone (O_3)	1 per month per treatment plant using O_3
Chlorite (daily sampling)	Distribution System entrance point	Daily per treatment plant using chlorine dioxide (ClO_2)	Daily per treatment plant using ClO_2
Chlorite (monthly sampling)	Distribution system: 1 near first customer, 1 in distribution system middle, 1 at max res time	3 sample sets per month	3 sample sets per month
Chlorine and Chloramines	Same points as total coliform	Same number as total coliform	Same number as total coliform
Chlorine Dioxide	Distribution system entrance point	Daily per treatment plant using ClO_2	Daily per treatment plant using ClO_2
*If system services a population of ≥10,000, at least 25 percent (1 out of each 4) of all samples collected each quarter must be at locations representing maximum residence time. Remaining samples taken at locations representative of at least average residence time in the distribution system and representing the entire distribution system, taking into account number of persons served, different sources of water, and different treatment methods.			

REDUCED MONITORING CAN BE REQUESTED

DBP	Location for Reduced Sampling	Reduced monitoring frequency and prerequisites
THMS and HAA5	In distribution system at point with max residence time	Surface water systems serving <10,000 and ground water systems serving >10,000 are reduced to 1/plant/year if: 1. system has completed at least 1 year of routine monitoring and 2. both TTHM and HAA5 running annual averages are no more than 40 µg/l and 30 µg/l, respectively. Samples must be taken during the month of warmest water temperature. Surface water systems serving <500 may not reduce monitoring to less than 1/plant/year Groundwater systems serving<10,000-reduced to 1/plant/3 years if: 1. system has completed at least 2 year of routine monitoring and both TTHM and HAA5 running annual averages are no more than 40 µg/l and 30 µg/l, respectively or 2. system has completed at least 1 year of routine monitoring and both TTHM and HAA5 annual samples are no more than 20 µg/l and 15 µg/l, respectively. Samples must be taken during the month of warmest water temperature.

DBP	Location for Reduced Sampling	Reduced monitoring frequency and prerequisites
Bromate	Distribution System entrance point	1 per quarter per treatment plant using O_3, if system demonstrates avg raw water bromide (a precursor to bromate) <0.05 mg/l (based on annual avg of monthly samples) then sampling may be reduced from monthly to quarterly.
Chlorite	Distribution System entrance point	Systems may reduce routine distribution system monitoring from monthly to quarterly if the chlorite concentration in all samples taken in the distribution system is below 1.0 mg/L for a period of one year.
Chlorine and Chloramines	NA	Monitoring may not be reduced.
Chlorine Dioxide		
Samples must be taken during representative operating conditions.		

TREATMENT TECHNIQUES FOR DISINFECTANTS AND DBPS

- Precursor Removal: Water systems that are under the direct influence of surface water and use conventional filtration treatment are required to remove specified percentages of organic materials (measured as total organic carbon) that may react with disinfectants to form DBPs. The rule establishes treatment technique requirements for removal of total organic carbon (TOC) to reduce the formation of DBPs by means of enhanced coagulation or enhanced softening. Treatment technique requirements are based on precursor (TOC) removal percent required for the individual source water flowing into the treatment plant (see chart below).
- Best Available Technology (BAT): Under the SDWA, EPA must specify the BAT for each MCL (or MRDL) that is set. PWS that are unable to achieve an MCL or MRDL may be granted a variance if they use the BAT.

	Disinfectant/DBP	BAT
Disinfectants	Chlorine Residual; Chloramine Residual; Chlorine Dioxide Residual	Control of treatment processes to reduce disinfectant demand and control disinfectant treatment processes to reduce disinfectant levels
DBPs	Total THM	Enhanced coagulation or enhanced softening or GAC10*, with chlorine as the primary and residual disinfectant
	Total HAA5	Enhanced coagulation or enhanced softening or GAC10*, with chlorine as the primary and residual disinfectant
	Chlorite	Control of treatment processes to reduce disinfectant demand and control of disinfection treatment processes to reduce disinfectant levels
	Bromate	Control of ozone treatment process to reduce production of bromate
*GAC10 means granular activated carbon with an empty bed contact time of 10 minutes and reactivation frequency for GAC of no more than six months.		

ENHANCED COAGULATION REQUIREMENT FOR CONTROL OF DBP PRECURSORS

Enhanced coagulation requirement has been developed to promote optimization of coagulation processes in conventional surface water treatment systems as required to improve removal of organic DBP precursors. Water systems that use surface water or ground water under the direct influence of surface water (Subpart H systems) and use conventional filtration treatment are required to remove specified percentages of organic materials, measured as total organic carbon (TOC), that may react with disinfectants to form DBPs.

Percent Required Removal of TOC by Enhanced Coagulation and Enhanced Softening			
Source Water TOC, mg/L	Source-water alkalinity, mg/L as $CaCO_3$ (in percentages)		
	0-60	>60-120	>120*
>2.0-4.0	35.0 %	25.0 %	15.0 %
>4.0-8.0	45.0 %	35.0 %	25.0 %
>8.0	50.0 %	40.0 %	30.0 %
*System practicing softening must meet the TOC removal requirements in this column.			

Alternative compliance criteria for enhanced coagulation and enhanced softening systems. The system is in compliance if it meets any of the following:

- The system's source water TOC level is less than 2.0 mg/L, calculated quarterly as a RAA.
- The system's treated water TOC level is less than 2.0 mg/L, calculated quarterly as a RAA.
- The TTHM and HAA5 running annual averages are no greater than 0.040 mg/L and 0.030 mg/L, respectively, and the system uses only chlorine for primary disinfection and maintenance of a residual in the distribution system.
- The system's source water SUVA, prior to any treatment and measured monthly, is less than or equal to 2.0 L/mg-m, calculated quarterly as a RAA.
- The system's finished water SUVA, measured monthly according, is less than or equal to 2.0 L/mg-m, calculated quarterly as a RAA.

Additional compliance criteria for softening systems. The system is in compliance if it meets any of the following:

- Softening that results in lowering the treated water alkalinity to less than 60 mg/L (as $CaCO_3$), measured monthly and calculated quarterly as a RAA.
- Softening that results in removing at least 10 mg/L of magnesium hardness (as $CaCO_3$), measured monthly and calculated quarterly as a RAA.

REPORTING AND RECORDKEEPING

The Stage 1 DBPR requires PWSs to report monitoring data to EPA or State within ten days after the end of the compliance period. For disinfection byproducts, systems must report the information specified in the following table directly to EPA.

If you are a…	You must report…
System monitoring for TTHM and HAA5 on a quarterly or more frequent basis	1. The number of samples taken during the last quarter. 2. The location, date and result of each sample taken during the last quarter. 3. The arithmetic average of all samples taken in the last quarter. 4. The annual arithmetic average of the quarterly arithmetic averages of this section for the last four quarters. 5. Whether the MCL was exceeded.
System monitoring for TTHM and HAA5 less frequently than quarterly (but at least annually)	1. The number of samples taken during the last year. 2. The location, date, and result of each sample taken during the last monitoring period. 3. The arithmetic average of all samples taken over the last year. 4. Whether the MCL was exceeded.
System monitoring for TTHM and HAA5 less frequently than annually	1. The location, date, and result of the last sample taken. 2. Whether the MCL was exceeded.
System monitoring for chlorite	1. The number of entry point samples taken each month for the last 3 months. 2. The location, date, and result of each sample (both entry point and distribution system) taken during the last quarter. 3. For each month in the reporting period, the arithmetic average of all samples taken in each three samples set taken in the distribution system. 4. Whether the MCL was violated, in which month, and how many times it was violated each month.
System monitoring for bromate	1. The number of samples taken during the last quarter. 2. The location, date, and result of each sample taken during the last quarter. 3. The arithmetic average of the monthly arithmetic averages of all samples taken in the last year. 4. Whether the MCL was violated.
Disinfectants	
System monitoring for chlorine or chloramines	1. The number of samples taken during each month of the last quarter. 2. The month arithmetic average of all samples taken in each month for the last 12 months. 3. The arithmetic average of the monthly averages for the last 12 months. 4. Whether the MRD was violated.
System monitoring for chlorine dioxide	• The dates, result, and locations of samples taken during the last quarter. • Whether the MRDL was violated. • Whether the MRDL was exceeded in any two consecutive daily samples and whether the resulting violation was acute (3 required distribution samples taken on day after a daily entry point sample MRDL exceed 0.8 mg/L).

PUBLIC NOTICE

For violations of the MCLs of contaminants or MRDLs of disinfectants that may pose an acute risk to human health, the PWS must provide a copy of the notice to the radio and television stations serving the area by the PWS as soon as possible but in no case later than 72 hours (3 days) after the violation. PWS are also required to contact EPA or in some instances a Tribal Nation reports to the State to inform them of violation within 24 hours.

EPA has provided some direct language that must be included in public notifications dependent on the exceeded disinfectant:

- Chlorine:
  "The United States Environmental Protection Agency (EPA) sets drinking water standards and has determined that chlorine is a health concern at certain levels of exposure. Chlorine is added to drinking water as a disinfectant to kill bacteria and other disease-causing microorganisms and is also added to provide continuous disinfection throughout the distribution system. Disinfection is required for surface water systems. However, at high doses for extended periods of time, chlorine has been shown to affect blood and the liver in laboratory animals. EPA has set a drinking water standard for chlorine to protect against the risk of these adverse effects. Drinking water which meets this EPA standard is associated with little to none of this risk and should be considered safe with respect to chlorine."
- Chloramine:
  "The United States Environmental Protection Agency (EPA) sets drinking water standards and has determined that chloramines are a health concern at certain levels of exposure. Chloramines are added to drinking water as a disinfectant to kill bacteria and other disease-causing microorganisms and are also added to provide continuous disinfection throughout the distribution system. Disinfection is required for surface water systems. However, at high doses for extended periods of time, chloramines have been shown to affect blood and the liver in laboratory animals. EPA has set a drinking water standard for chloramines to protect against the risk of these adverse effects. Drinking water which meets this EPA standard is associated with little to none of this risk."
- Chlorine dioxide:
  "The United States Environmental Protection Agency (EPA) sets drinking water standards and has determined that chlorine dioxide is a health concern at certain levels of exposure. Chlorine dioxide is used in water treatment to kill bacteria and other disease-causing microorganisms and can be used to control tastes and odors. Disinfection is required for surface water systems. However, at high doses, chlorine dioxide-treated drinking water has been shown to affect blood in laboratory animals. Also, high levels of chlorine dioxide given to laboratory animals in drinking water have been shown to cause neurological effects on the developing nervous system. These neurodevelopmental effects may occur as a result of a short-term excessive chlorine dioxide exposure. To protect against such potentially harmful exposures, EPA requires chlorine dioxide monitoring at the treatment plant, where disinfection occurs, and at representative points in the distribution system serving water users. EPA has set a drinking water standard for chlorine dioxide to protect against the risk of these adverse effects.
  - *The chlorine dioxide violations reported today are the result of exceedances at the treatment facility only, and do not include violations within the distribution system serving users of this water supply. Continued*

compliance with chlorine dioxide levels within the distribution system minimizes the potential risk of these violations to present consumers.

- *The chlorine dioxide violations reported today include exceedances of the EPA standard within the distribution system serving water users. Violations of the chlorine dioxide standard within the distribution system may harm human health based on short-term exposures. Certain groups, including pregnant women, infants, and young children, may be especially susceptible to adverse effects of excessive exposure to chlorine dioxide treated water. The purpose of this notice is to advise that such persons should consider reducing their risk of adverse effects from these chlorine dioxide violations by seeking alternate sources of water for human consumption until such exceedances are rectified. Tribal and State health authorities are the best sources for information concerning alternate drinking water"*

- Disinfection byproducts and treatment technique for DBPs:
  "The United States Environmental Protection Agency (EPA) sets drinking water standards and requires the disinfection of drinking water. However, when used in the treatment of drinking water, disinfectants react with naturally occurring organic and inorganic matter present in water to form chemicals called disinfection byproducts (DBPs). EPA has determined that a number of DBPs are a health concern at certain levels of exposure. Certain DBPs, including some trihalomethanes (THMs) and some haloacetic acids (HAAs), have been shown to cause cancer in laboratory animals. Other DBPs have been shown to affect the liver and the nervous system and cause reproductive or developmental effects in laboratory animals. Exposure to certain DBPs may produce similar effects in people. EPA has set standards to limit exposure to THMs, HAAs, and other DBPs."
- Bromate:
  "The United States Environmental Protection Agency (EPA) sets drinking water standards and has determined that bromate is a health concern at certain levels of exposure. Bromate is formed as a byproduct of ozone disinfection of drinking water. Ozone reacts with naturally occurring bromide in the water to form bromate. Bromate has been shown to produce cancer in rats. EPA has set a drinking water standard to limit exposure to bromate."
- Chlorite:
  "The United States Environmental Protection Agency (EPA) sets drinking water standards and has determined that chlorite is a health concern at certain levels of exposure. Chlorite is formed from the breakdown of chlorine dioxide, a drinking water disinfectant. Chlorite in drinking water has been shown to affect blood and the developing nervous system. EPA has set a drinking water standard for chlorite to protect against these effects. Drinking water which meets this standard is associated with little to none of these risks and should be considered safe with respect to chlorite."