

## Question & Answer:

# What is the Disinfection By-Products Rule?

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### What are disinfection by-products?

Chlorine is the most widely used water disinfectant due to its effectiveness and cost. Using chlorine as a drinking water disinfectant has prevented millions of water borne diseases, such as typhoid, cholera, dysentery, and diarrhea. Most states require community water systems to use chlorination.

However, research shows that chlorine has side effects. It reacts with organic matter present in water and forms a series of compounds that have been linked to cancer in animals. These compounds are called disinfection by-products (DBPs).

All disinfectants form DBPs in one of two reactions: (1) chlorine and chlorine-based compounds (halogens) react with organics in water causing the chlorine atom to substitute other atoms resulting in halogenated by-products and (2) oxidation reactions, where chlorine oxidizes compounds present in water.

Secondary by-products are also formed when multiple disinfectants are used.

### Where does this organic matter originate?

All living organisms have carbon as an essential element in their cells. When trees shed their leaves, they start decomposing and are ultimately broken down by bacteria into carbon-containing compounds. Similarly, dead animals on land and fish and other aquatic life decompose and disintegrate into compounds that contain carbon as an essential element. Hence, all surface water and groundwater contain varying amounts of carbon-containing compounds called organic matter (primarily humic and fulvic acids).

### What are the types of DBPs?

Disinfection can produce hundreds of by-products when chlorine reacts with organic matter. Two major classes, trihalomethanes (THMs) and haloacetic acids (HAA), make up the bulk of these by-products. The four THMs include chloroform, bromoform, bromodichloromethane, and

dibromochloromethane. There are five HAAs—chloroacetic acid, dichloroacetic acid, trichloroacetic acid, bromoacetic acid, and dibromoacetic acid—that are commonly abbreviated HAA5. In addition, there are a variety of other compounds, such as haloacetonitriles, halo ketones, haloaldehydes, chloropicrin, cyanogens chloride, and chlorophenols. Alternative disinfectants, such as chloramines, chlorine dioxide, and ozone, can also react with organics to form organic byproducts.

Temperature, time, and water pH, along with the disinfection process and other source water characteristics, determine what DBPs will form. Most reactions that form DBPs occur in the first 24 hours. The pH determines, in part, which DBP will be formed, resulting in risks and risk tradeoffs. For example, lowering pH to control for trihalomethane (THM) formation can result in the increased formation of trihaloacetic acids.



Reaction time is also an important variable. For example, chloral hydrate is unstable at high pH levels, and over time, it degrades to chloroform, which results in increased THMs.

### What does the DBP Rule say?

The Disinfection By-Products Rule (DBPR) has two stages. In 1979, the U.S. Environmental Protection Agency (EPA) adopted regulations that established a maximum contaminant level (MCL) of 0.1 mg/L for total trihalomethane (THM). In 1998, the Stage 1 DBPR was established. This rule updated and superceded the original THM limits. A Stage 2 DBPR has been proposed that will supplement the Stage 1 rule and require systems to comply with by-product MCLs based on locations in the distribution system.

### Stage 1 DBPR

The Stage 1 DBPR applies to community water systems and non-transient non-community systems that add a disinfectant to the drinking water during any part of the treatment process, including those serving fewer than 10,000 people. For systems that serve more than 10,000 customers, the rule took effect on January 1, 2002. For systems that serve fewer than 10,000 customers, the rule took effect on January 1, 2004. The Stage 1 DBPR establishes seven new standards and a treatment technique of enhanced coagulation and enhanced softening to further reduce DBP exposure. The standard applies to all systems that add chlorine, chloramines, or chlorine dioxide as a disinfectant.

The Stage 1 DBPR requires new maximum residual

disinfectant levels (MRDLs) for chlorine (4 mg/L), chloramines (4 mg/L), and chlorine dioxide (0.8 mg/L). MRDLs are similar to MCLs but are applicable to disinfectants. The MRDLs keep disinfectant levels low enough to minimize DBP formation and limit adverse health effects.

The rule specifies MCLs for four trihalomethanes:

- chloroform (0);
- bromodichloromethane (0);
- dibromochloromethane (0.06 mg/L); and
- bromoform (0).
- MCLs for total trihalomethanes (the sum of the four listed above) cannot exceed 0.080 mg/L.
- The rule sets MCLs for haloacetic acids:
  - dichloroacetic acid (0);
  - trichloroacetic acid (0.3 mg/L);
  - bromate (0); and
  - chlorite (0.8 mg/L).

**Table 1 Stage 1 Disinfectants and Disinfection Byproducts Rule**

DISINFECTANT RESIDUAL	MRDLG (mg/L)	MRDL (mg/L)	COMPLIANCE BASED ON
Chlorine	4 (as Cl <sub>2</sub> )	4.0 (as Cl <sub>2</sub> )	Annual Average
Chloramine	4 (as Cl <sub>2</sub> )	4.0 (as Cl <sub>2</sub> )	Annual Average
Chlorine Dioxide	0.8 (as ClO <sub>2</sub> )	0.8 (as ClO <sub>2</sub> )	Daily Samples
DISINFECTION BYPRODUCTS	MCLG (mg/L)	MCL (mg/L)	COMPLIANCE BASED ON
Total trihalomethanes (TTHM) <sup>1</sup>	N/A	0.080	Annual Average
- Chloroform	***		
- Bromodichloromethane	0		
- Dibromochloromethane	0.06		
- Bromoform	0		
Haloacetic acids (five) (HAA5) <sup>2</sup>	N/A	0.060	Annual Average
- Dichloroacetic acid	0		
- Trichloroacetic acid	0.3		
Chlorite	0.8	1.0	Monthly Average
Bromate	0	0.010	Annual Average

Source: [www.epa.gov/safewater/mdbp/dbp1.html](http://www.epa.gov/safewater/mdbp/dbp1.html)

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Total haloacetic acids—a sum of those listed above plus monochloroacetic acid, mono- and dibromoacetic acids—must fall below 0.060 mg/L.

MCLS are also established for two inorganic disinfection byproducts: chlorite (1.0 mg/L) and bromate (0.010 mg/L) and the treatment technique of enhanced coagulation and lime softening for removal of natural organic matter is required.

The Stage 1 rule requires a monitoring plan that outlines schedules for collecting DBP samples and at what locations. The plan must cover the entire distribution system. The number of people that the system serves determines sampling frequency. Table 1 gives the frequency of samples.

### Stage 2 Rule

The Stage 2 DBPR will supplement the Stage 1 rule and will require water systems to meet disinfection MCLs at each monitoring site in the distribution system. The rule also seeks to better identify monitoring sites that include pockets where high concentration of DBPs are suspected. The Stage 2 DBPR is one part of the Stage 2 Microbial and Disinfection Byproducts Rules (M-DBP), a set of interrelated regulations that address risks from microbial pathogens and disinfectants/disinfection byproducts (D/DBPs).

The Stage 2 DBPR requires that systems do a self-assessment and identify locations within a distribution system that have higher residence time of liquid sitting stagnant (pockets). Samples would have to be taken at these sites. The U.S. Environmental Protection Agency (EPA) calls this the initial distribution system evaluation.

Under the Stage 2 rule, maximum contaminant levels of TTHM and HAA5s will be measured or calculated at each monitoring site. This is called a locational running annual average (i.e., running yearly averages of each sample collected at the specified location). The Stage 2 rule is more difficult to meet because DBP levels in some portions of a distribution system can get higher than when water is just sitting at that point. Compliance is based on a running annual average of monthly averages of all compliance samples collected in the previous 12 months

## Where can I find more information?

The U.S. Environmental Protection Agency Web site has information about disinfection by-products (DBPs). For an overview of DBPs, visit [www.epa.gov/OGWDW/mdbp.html](http://www.epa.gov/OGWDW/mdbp.html). For more about the Stage 2 DBPR, visit [www.epa.gov/safewater/stage2/](http://www.epa.gov/safewater/stage2/) and [www.epa.gov/safewater/stage2/pdfs/fact\\_%20st2\\_proposed.pdf](http://www.epa.gov/safewater/stage2/pdfs/fact_%20st2_proposed.pdf).

For more information about the Stage 1 rule, visit [www.epa.gov/safewater/mdbp/mdbp.html#st1](http://www.epa.gov/safewater/mdbp/mdbp.html#st1) and [www.epa.gov/safewater/mdbp/st2dis.html](http://www.epa.gov/safewater/mdbp/st2dis.html).

for each monitoring location. Compliance must be calculated each quarter, using the results from the previous year. Any running annual average of monthly averages that exceeds the MRDL is considered a violation.

The Stage 2 rule also requires that systems find out if they experience spikes in DBP levels. Systems experiencing such spikes, termed “significant excursions,” are required to review their operational practices and work with the state primacy agency.

### Are there special provisions for small systems

Small systems are given additional time to comply with the Stage 1 rule. Large surface water systems had to comply with the Stage 1 DBPR and the Interim Enhanced Surface Water Treatment Rule by January 2002. Groundwater systems and small surface water systems must comply with the Stage 1 DBPR by January 2004.

### What are the health effects of DBPs?

DBPs have been linked to bladder and rectum cancer, and may also have reproductive and developmental effects. Chloroform affects liver and kidney function in humans in both acute and long-term exposures. In lab studies on mice and rats, three THMs (bromoform, bromodichloromethane, and dibromochloromethane) caused changes in kidney, liver, and serum enzyme levels and decreased body weight.

Dichloroacetic acid (DCA) and trichloroacetic acid (TCA) are found more often among the HAA5s. EPA has classified DCA as a human carcinogen. Studies

# Related Products Available from NESC

The National Environmental Services Center has several products related to DBPs and the Stage 1 and Stage 2 DBP rules.



## Using DWSRF Funds to Comply with the Stage 1 Disinfectants And Disinfection By-Products Rule

Product # DWFSRG75

The drinking water state revolving fund (DWSRF) program provides grants to states for low interest loans to eligible systems for infrastructure improvements needed to comply with SDWA mandates, in this case the Stage 1 Disinfectants and Disinfection By-Products Rule. The fact sheet outlines: (1) the rule and how DWSRF can help systems comply, (2) treatment options, (3) who must comply and how it will impact systems and (4) rule deadlines and requirements

## Stage 1 Disinfectants and Disinfection By-Products Rule

Product # DWFSRG92

Drinking water disinfection has been a major factor in reducing disease epidemics in the U.S. But, the disinfectants themselves can react with naturally occurring materials in water to form byproducts that may pose health risks. This fact sheet discusses public health concerns and requirements for compliance of the Stage 1 Disinfectants and Disinfection By-Products Rule.

## Stage 1 Disinfectants/Disinfection By-Products Rule : Frequently Asked Questions

Product # DWBLRG93

Information about the Stage 1 Disinfectants and Disinfection By-Products Rule can be found with the help of this booklet. Sections cover disinfectants such as chlorine, chloramines, and chlorine dioxide and by-products that can result from their application to drinking water treatment.

Monitoring issues are discussed, as well as primacy, violations, and reporting requirements.

## Drinking Water Chlorination: A review of Disinfection Practices and Issues

Product # DWBLPE114

Waterborne diseases continue to present challenges to public health officials and water suppliers. Prevention and control through source water protection and proper treatment techniques are critically important. The booklet discusses the benefits of chlorination, risks from disinfection by-products, and alternative treatment processes.

## Controlling Disinfection By-Products and Microbial Contaminants in Drinking Water

Product # DWBKOM16

Drinking water utilities in the U.S. have played the major role in protecting public health through the reduction of waterborne diseases. Unfortunately, some drinking water disinfection processes create potentially harmful by products. This report describes the regulations that have been promulgated since passage of the Safe Drinking Water Act, discusses related disinfection by-product regulations, and reviews trends that have developed with respect to compliance with SDWA. It also summarizes and reviews treatment technology research conducted by the U.S. Environmental Protection Agency since 1981.

## Stage 1 Disinfectants and Disinfection By-Product Rules: A Quick Reference Guide

Product # DWFSOM11

Some disinfectants and disinfection by-product

ucts (DBPs) cause cancer and reproductive problems in people. The Stage 1 Disinfectants and Disinfection By-Products (DBP) Rule is first of a set of rules that will reduce the allowable levels of DBPs in drinking water. The fact sheet gives managers and water operators an overview of the rule, the regulated contaminants/disinfectants, public health benefits from reduced DBPs, and requirements for drinking water systems.

## Microbial and Disinfection By-Products Rules Compliance Guidance Manual

Product # DWBKRG61

The microbial Disinfectants and Disinfection By-Products Rule (DBP) addresses acute threats from microbial contamination and chronic threats from disinfectant residual and by-products of disinfection. This manual describes the DBP rules and potential conflicts that may arise as systems comply. Plus, it provides possible solutions and approaches to resolve these conflicts.

## Disinfection Problems and Benchmarking Guidance Manual

Product # DWBKMG39

Water systems are required to develop a profile for *Giardia* if their distribution system DBPs exceed certain concentrations. This document gives information on implementing disinfection profiling and compliance of daily *Giardia* and /or virus log inactivation over a period of one year.

### How to Order These Products

To order any of these products, call NESC at (800) 624-8301, fax (304) 293-3161, or e-mail [info@mail.nesc.wvu.edu](mailto:info@mail.nesc.wvu.edu). Make sure to include the products you want, their corresponding product number, and your name, organization, address, and phone number with each order. Quantities are limited to one per order. If you need bulk copies, please call to make arrangements.



conducted on humans showed that a DCA exposure for six to seven days at 43 to 57 mg/kg/day resulted in mild sedation, reduced blood glucose, reduced plasma lactate, reduced plasma cholesterol, and reduced triglyceride levels. Studies in mice and rats showed that it causes liver tumors. Studies have shown that TCA can produce developmental malformations in rats, particularly in cardiovascular systems.

### **What are ways to minimize DBPs?**

There are four ways to deal with DBPs: (1) minimize precursors, (2) reduce disinfectant doses, (3) remove DBPs after they form, and (4) use alternative disinfectants.

### **Minimizing Precursors**

One way to prevent DBPs is to prevent the occurrence of natural organic matter (precursors) in the source water. This can be done by either reducing the precursor content of raw water, such as blending source waters, removing precursors by treatment in the plant, by disinfecting the water after all other treatment has been completed, or a combination of the three. Natural organic matter levels can be reduced by adsorption with granular activated carbon and through coagulation using alum and ferric salts.

### **Reducing Disinfectant Dosages**

Reducing the primary and secondary disinfection dosages and having booster chlorination later in the distribution system can help reduce disinfection loads. Avoiding prechlorination altogether means the organic matter won't come in contact with chlorine. Having an anthracite layer in the filter or feeding activated carbon before the filtration step will adsorb organic matter before filtration. Chlorination can then be done later.

### **Removing DBPs**

EPA has specified best available technologies for removing THMs and HAA5s: enhanced coagulation, enhanced softening, or granular activated carbon. However, these methods are expensive and must be used only after other methods have been tried.

### **Alternative Disinfectants**

Alternative disinfectants are ultraviolet light, potassium permanganate, ozone, or a combination of chlorine dioxide and chloramines. Some states do not recognize

alternative disinfectants and will not approve their usage unless they are used along with chlorine or chloramines that provide a residual.

Ozone is a powerful disinfectant that does not produce chlorinated organics, but it does result in other by-products. Ozone does not have a residual, so it is used along with chloramines that will provide a residual. UV disinfection also has the same problem of no residual so chloramines or chlorine are used to provide the required disinfection residual in the distribution system. UV is not effective for turbid waters and UV effectiveness decreases with increasing turbidity. Unfortunately, none of the other disinfectants are as economical as chlorine. Systems should check with their primary agency before selecting alternative disinfectants.

### **What is the timeline for the Stage 2 Rule?**

EPA conducted its first meeting about the Stage 2 rule in March 1999. The last public hearing on the Stage 2 Rule was in January 2005 with a final rule expected soon.

### **References**

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- HDR Engineering, Inc. 1991. *Handbook of Public Water Systems, 2nd edition*. Omaha, NE: John Wiley and Sons.



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