# Chapter 1

# Regulated Contaminants and Treatment Challenges

Regulations that govern US water supply and treatment are developed by the US Environmental Protection Agency (USEPA) under the Safe Drinking Water Act (SDWA). Most states administer USEPA regulations after adopting regulations that are no less stringent than federal rules; and in some cases, states have adopted stricter regulations or have developed regulations for additional contaminants not regulated by USEPA.

This chapter discusses current and anticipated USEPA regulations and the challenges that operators face in their efforts to comply with the regulations. Water system operators should consult their local and state regulatory agencies to verify applicable regulations that may be different than the federal regulations listed in this chapter. The chapter concludes with a discussion of selected contaminants that are commonly found in water, their significance, and the methods for their removal.

## TYPES OF WATER SYSTEMS

The SDWA defines a public water system (PWS) as a supply of piped water for human consumption that has at least 15 service connections, or serves 25 or more persons 60 or more days each year. By that definition, private homes, groups of homes with a single water source but having fewer than 25 residents, and summer camps with their own water source that operate less than 60 days per year are not PWSs. They may, however, be subject to state or local regulations. Such systems may also be subject to state and local well construction and water quality requirements.

PWSs are classified into three categories based on the type of customers served:

- *Community PWS:* a system whose customers are full-time residents
- *Nontransient noncommunity PWS:* an entity having its own water supply, serving an average of at least 25 persons who do not live at the location but who use the water for more than 6 months per year

- *Transient noncommunity PWS*: an establishment having its own water system, where an average of at least 25 people per day visit and use the water occasionally or for only short periods of time

The rationale for these classifications is based on the differences in exposure to contaminants experienced by persons using the water. Most chemical contaminants are believed to potentially cause adverse health effects from long-term exposure. Short-term exposure to low-level chemical contamination may not carry the same risk as long-term exposure.

Therefore, the monitoring requirements for both community and noncommunity water systems apply to all contaminants that are considered a health threat. The transient and nontransient noncommunity systems must only monitor for nitrite and nitrate, as well as biological contamination (those that pose immediate threat from brief exposure). The remaining community systems, about 52,000 in the United States, have more stringent and frequent monitoring requirements.

Before examining the specific regulations that govern contaminants, the operator needs to know the difference between the two concepts used in the contaminant monitoring process: the maximum contaminant level goal (MCLG) and the maximum contaminant level (MCL).

- The MCLG is set for most substances at a level where there are no known, or anticipated, health effects. For those substances that are suspected carcinogens, the MCLG is set at zero.
- The MCL is set as close as feasible to the MCLG for substances regulated under the SDWA. The MCL is a level that is reasonably and economically achievable. This is the enforceable regulated level. Water systems that exceed an MCL must take steps to install treatment to reduce the contaminant concentration to below the MCL. Where USEPA has found it impractical to set an MCL, a treatment technique (TT) has been established instead of an MCL.

With these concepts in mind, the various regulations can be examined. This discussion is not meant to be all-inclusive. Because the regulatory process is an ever-evolving one, the reader is cautioned that some of the stated facts presented in this discussion may have changed since the writing of this chapter. For up-to-date information, it is best to contact the local office of the regulatory authority in the district or state where the utility operates.

Table 1-1 contains some of the more common regulated contaminants and their respective MCL or treatment technique (TT) descriptions. These are provided for illustration only and are not intended to be used for regulatory purposes (see the official USEPA regulatory information on the agency website).

Operations personnel are expected to know the regulatory limits for compounds encountered in their water supply. However, the number and variety of regulated substances make it unlikely that operators would know all of the regulatory limits. Operators must rely on current references for the most accurate information. These are available from the regulatory agency responsible for the location of the treatment plant.

**Table 1-1 Selected USEPA drinking water standards**

| Contaminant | MCL or TT (mg/L)* |
|---|---|
| Total coliform | 5 percent (monthly positives) |
| Turbidity | 0.3 ntu monthly or 1 ntu† |
| Chlorite | 1.0 |
| HAA5 | 0.060 |
| TTHM | 0.080 |
| Chloramines (as $Cl_2$) | 4.0 |
| Chlorine (as $Cl_2$) | 4.0 |
| Chlorine dioxide (as $ClO_2$) | 0.8 |
| Arsenic | 0.010 |
| Copper | TT, Action level = 1.3 |
| Cyanide (as free cyanide) | 0.2 |
| Fluoride | 4.0 |
| Lead | TT; Action Level = 0.015 |
| Mercury (inorganic) | 0.002 |
| Nitrate (measured as nitrogen) | 10 |
| Nitrite (measured as nitrogen) | 1 |
| Radium 226 and 228 (combined) | 5 pCi/L |
| Uranium | 10 µg/L |

*The listed standards are numerical representations of the current USEPA drinking water standard and do not include the sample frequency or location and other important compliance information. For a complete definition of the standards consult USEPA Drinking Water Standards.

†Turbidity less than or equal to 0.3 nephelometric turbidity units (ntu) for the combined filter effluent for 95% of the monthly samples. At no time can turbidity be above 1 ntu.

## DISINFECTION BY-PRODUCT AND MICROBIAL REGULATIONS

Drinking water treatment, including use of chemical disinfectants such as chlorine, ozone, and chlorine dioxide, has been an important step in protecting drinking water consumers from exposure to harmful microbial contaminants. However, these chemical disinfectants can also react with organic and inorganic substances in the water to produce by-products that may be harmful to drinking water consumers, particularly some susceptible segments of the population. Therefore, drinking water treatment using chemical disinfectants involves a delicate balancing act, i.e., adding enough disinfectant to control harmful microorganisms but not enough to produce unacceptably high levels of regulated disinfection by-products (DBPs).

The USEPA has enacted several regulations impacting microbial control and production of DBPs in groundwater and surface water supplies for small and large public drinking water systems. These rules are referred to collectively as the Microbial/Disinfection By-Products (M/DBP) Rules. Microbial protection for consumers of drinking water from public supplies is provided by provisions of current or pending rules listed below and discussed in more detail later in this chapter:

- Filter Backwash Recycling Rule (FBRR)
- Ground Water Rule (GWR)
- Interim Enhanced Surface Water Treatment Rule (IESWTR)
- Long-Term 1 Surface Water Treatment Rule (LT1ESWTR)
- Long-Term 2 Surface Water Treatment Rule (LT2ESWTR)
- Stage 1 Disinfectants and Disinfection By-products Rule (Stage 1 DBPR)
- Stage 2 Disinfectants and Disinfection By-products Rule (Stage 2 DBPR)
- Surface Water Treatment Rule (SWTR)
- Total Coliform Rule (TCR)

Provisions of the Disinfectants and Disinfection By-products Rule (DBPR) are intended to protect drinking water consumers against the unintended public health consequences associated with consumption of treated drinking water containing residual disinfectants and DBPs produced from degradation of these residual disinfectants or reaction of disinfectants with organic and inorganic DBP precursors.

More details regarding the DBPR, including the current Stage 1 and 2 DBPR, are described in this chapter. Also included in the DBPR description is a brief discussion of some currently unregulated DBPs that are being heavily researched and may be the subject of future regulation. In the following discussion, the DBPR will be discussed first, followed by the microbial protection rules (SWTR, GWR, and TCR/DSR).

## DBPR

The Stage 1 and 2 DBPR requirements discussed in the following sections focus first on two specific contaminants (TTHM and HAA5), and then on other aspects of these regulations dealing with control or removal of DBP precursors ("enhanced coagulation"), bromate, chlorite, and residual disinfectants.

### *Stage 1 DBPR—HAA5 and TTHM Provisions*

The Stage 1 DBPR was published in 1998 and established an MCL of 0.080 mg/L for TTHM (the sum of four trihalomethanes, which are chloroform, bromodichloromethane, dibromochloromethane, and bromoform) and 0.060 mg/L for HAA5 (the sum of five specific haloacetic acids, which are mono-, di-, and tri-chloroacetic acids plus mono- and dibromoacetic acids). Although the MCLs for TTHM and HAA5 were officially written as 0.080 mg/L and 0.060 mg/L, respectively, the limits are commonly referred to as "80/60," or 80 μg/L and 60 μg/L. Although the numerical value of each MCL is an important consideration, an understanding of the methodology used to calculate the compliance value in order to compare it to this MCL is a subtle and equally important consideration in understanding compliance with the DBPR.

For TTHM and HAA5, the compliance value is determined by monitoring the distribution system. Compliance monitoring locations need to be representative of the distribution system. Systems serving >10,000 persons that use surface water sources are required to monitor at least four locations per plant, meaning that distribution systems fed by more than one treatment plant must have at least four monitoring locations designated for each plant entry point.

The compliance monitoring location for systems with only one monitoring point must be representative of maximum residence time in the distribution system. A minimum of one out of every four compliance monitoring locations for systems with more locations must also be representative of maximum residence time. The other locations must be far enough away from the plant entry points to be representative of average residence time in the distribution system.

Unlike acute toxicity risks, for which the exposure could be a single glass of water, cancer risks like those believed to be linked to TTHM and HAA5 involve longer periods of exposure (daily glasses of water spanning decades). For chronic exposures such as these, exposure to an excessively high concentration of a given cancer-causing agent will not necessarily result in the consumer getting cancer from this source. Conversely, a consumer exposed to a lower concentration every day for a lifetime could be more likely to develop cancer. Therefore, regulation of DBPs to reduce cancer risks is *not* based on limiting exposure to a single incident (i.e., not a "single hit"), but rather is aimed at reducing the repeated exposure over time. In other words, DBP exposure needs to be evaluated on an average basis over time.

Under the Stage 1 DBPR, 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 at each plant. Most systems are required to monitor quarterly (i.e., 4 times per year), although small groundwater systems (<10,000 persons) may be allowed to sample once a year. Typically, the RAA is based on 4 monitoring locations sampled quarterly, meaning RAA will be the average of 16 monitoring results each for HAA5 and TTHM.

Table 1-2 illustrates one facility's calculations of RAA for HAA5 that were used for Stage 1 compliance (this table also shows calculation of values for Stage 2 DBPR, which will be discussed later). It is important to reemphasize that compliance is based solely on the RAA, not on a single quarterly result at any one monitoring location. Consequently, it is *not* correct to refer to a single quarterly monitoring result above 60 µg/L for HAA5 or above 80 µg/L for TTHM as being above the MCL. Therefore, even though several individual monitoring values in Table 1-2 are greater than 60 µg/L, the facility is in compliance with the HAA5 MCL because the RAA is 45 µg/L for HAA5.

Utility personnel should be consistent and rigorous in their use of terminology when dealing with the general public or with state and local health officials, and should ensure that all people participating in these discussions are consistent in applying the MCL only to RAA values and do not make the common mistake of referring to a single quarterly monitoring value as being "above the MCL."

### *Stage 2 DBPR—HAA5 and TTHM Provisions*

The Stage 2 DBPR, published in 2006, is now in effect. This rule tightened requirements for DBPs, but compliance is not achieved by modifying the numerical value of the MCLs or by requiring monitoring of new constituents. Instead, the rule makes compliance more challenging than under the Stage 1 DBPR by (1) changing the way the compliance value is calculated and (2) changing the compliance monitoring locations to sites representative of the greatest potential for THM and HAA formation. These changes were made to ensure uniform compliance with the DBP standards across all areas of the distribution system, i.e., compliance is required at each sampling location.

The compliance value in the Stage 2 DBPR is called the *locational running annual average* (LRAA), and it is calculated by separately averaging the four quarterly samples at each monitoring location. Compliance is based on the maximum LRAA value (see Table 1-2). Furthermore, the Stage 2 DBPR included several interim steps that led to the replacement of many existing Stage 1 DBPR monitoring locations with new locations representative of the greatest potential for consumer exposure to high levels of TTHM and HAA5.

The Stage 2 DBPR required that facilities maintain compliance with the Stage 1 DBPR using the existing monitoring locations during the first three years after the final version of the Stage 2 DBPR was published. In the time period between the third and sixth year after the Stage 2 DBPR was published, compliance continues to be based on maintaining 80/60 (TTHM and HAA5) or lower for RAA; it also includes a requirement for maximum LRAA at existing Stage 1 monitoring locations. The long-term goal of the Stage 2 DBPR was to identify locations within the distribution system with the greatest potential for either TTHM or HAA5 formations and then base compliance on the LRAA at or below 80/60 for each of these locations. Many of these locations were identified during the initial distribution system evaluation (IDSE).

**Table 1-2 Example RAA and LRAA calculations for Stage 1 and 2 DBPR**

| | | Sampling Location, *μg/L* | | | |
|---|---|---|---|---|---|
| **Year** | **Quarter** | **A** | **B** | **C** | **D** |
| 1 | 3rd | 52 | 68 | 63 | 66 |
| 1 | 4th | 35 | 42 | 38 | 41 |
| 2 | 1st | 47 | 49 | 42 | 43 |
| 2 | 2nd | 18 | 42 | 45 | 37 |
| LRAA | | 38 | 50 | 47 | 47 |
| Maximum LRAA | | | 50 | | |
| RAA | | | 45 | | |

The IDSE included monitoring, modeling, and/or other evaluations of drinking water distribution systems to identify locations representative of the greatest potential for consumer exposure to high levels of TTHM and HAA5. The goal of the IDSE was to evaluate a number of potential monitoring locations to justify selection of monitoring locations for long-term compliance (i.e., Stage 2B) with the Stage 2 DBPR.

One item to note regarding the Stage 2 DBPR as it applies to TTHM and HAA5 is that the goal was to find the locations in the distribution system where average annual levels of these DBPs are highest. TTHM formation increases as contact time with free or combined chlorine increases, although formation in presence of combined chlorine is limited. Therefore, establishing points in the distribution system with highest potential for TTHM formation is related to points with maximum water age. Utilities that have not performed a tracer study in the distribution system to determine water age should consider doing so.

By contrast, peak locations for HAA5 are more complicated because microorganisms in biofilm attached to distribution system pipe surfaces can biodegrade HAA5. Consequently, increasing formation of HAA5 over time is offset by biodegradation, eventually reaching a point where HAA5 levels decrease over time, even to the point where they drop to zero. Figure 1-1 shows gradual reduction in HAA5 formation over time in a distribution system, followed by eventual decrease of HAA5 as water age increases (water age measured in tracer test). In chloramination systems, HAA5 formation is limited. In fact, ammonium chloride is added as a quenching agent in HAA5 compliance samples in order to halt HAA5 formation prior to analysis (*Standard Methods for the Examination of Water and Wastewater,* latest edition). Therefore, little additional HAA5 formation occurs after chloramination to offset HAA5 biodegradation occurring in the distribution system.

### *Enhanced Coagulation Requirement of the Stage 1 and 2 DBPR*

The 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. The focus of the SWTR is separate from that of the enhanced coagulation requirement, with the former directed toward optimizing particle removal and the latter toward optimizing removal of natural organic matter (DBP precursors). Both promote efforts by water utilities to properly control and optimize coagulation processes and reduce DBP formation.

The enhanced coagulation requirements require treatment plants to remove specific percentages of total organic carbon (TOC) based on their source water TOC and alkalinity levels. Facilities must meet the enhanced coagulation requirements unless they meet any of the following exemptions (USEPA Stage 1 DBPR Guidance):

1. The PWS's source water TOC level is <2.0 mg/L, calculated quarterly as a running annual average.

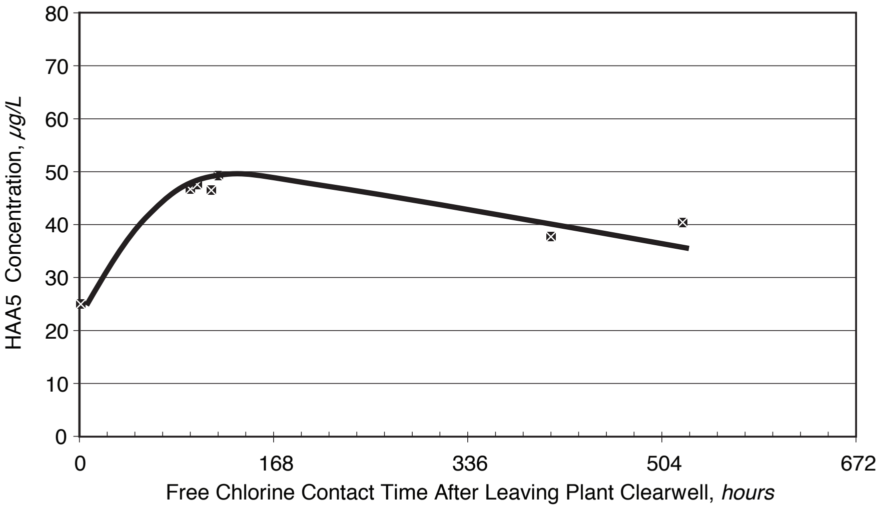


**Figure 1-1 Formation and decay of HAA5 in a distribution system (time estimated by fluoride tracer test—$T_{100}$)**

2. The PWS's treated water TOC level is <2.0 mg/L, calculated quarterly as a running annual average.
3. The PWS's source water TOC level is <4.0 mg/L, calculated quarterly as a running annual average; the source-water alkalinity is >60 mg/L (as $CaCO_3$), calculated quarterly as a running annual average; and either the TTHM and HAA5 running annual averages are no greater than 0.040 mg/L and 0.030 mg/L, respectively; or the PWS has made a clear and irrevocable financial commitment to use technologies that will limit the levels of TTHMs and HAA5 to no more than 0.040 mg/L and 0.030 mg/L, respectively.
4. The PWS's TTHM and HAA5 running annual averages are no greater than 0.040 mg/L and 0.030 mg/L, respectively; and the PWS uses only chlorine for primary disinfection and maintenance of a residual in the distribution system.
5. The PWS's source water specific ultraviolet absorption at 254 nm (SUVA), prior to any treatment and measured monthly, is ≤2.0 L/mg-m, calculated quarterly as a running annual average.
6. The PWS's finished-water SUVA, measured monthly, is ≤2.0 L/mg-m, calculated quarterly as a running annual average.

Additionally, alternative compliance criteria for softening systems include the following:

7. Softening that results in lowering the treated water alkalinity to <60 mg/L (as $CaCO_3$), measured monthly and calculated quarterly as a running annual average.

8. Softening that results in removing at least 10 mg/L of magnesium hardness (as $CaCO_3$), measured monthly and calculated quarterly as a running annual average.

Utilities that cannot meet these avoidance criteria should know their enhanced coagulation endpoint, identified as the coagulant dosage and/or pH value that, when achieved, no longer produces significant TOC reduction. Specifically, when the source water TOC is not reduced by at least 0.3 mg/L with an incremental dosage increase of 10 mg/L alum (or equivalent ferric salt) and the pH value of the source reaches a value listed in Table 1-3, the enhanced coagulation endpoint has been reached.

If a utility is not exempt, a number of steps have to be evaluated relating to TOC removal, alkalinity of source water, range of source water TOC, required TOC removal for given source water characteristics, and several other factors.

### *Bromate*

The bromate MCL from the Stage 1 DBPR remained at 0.010 mg/L for the Stage 2 DBPR. Bromate can be present in systems using ozone that have bromide present at the ozone application point. Bromate is also potentially formed during manufacture and storage of sodium hypochlorite. Consequently, systems using ozone for oxidation or disinfection are required to monitor once a month at distribution system entry point for bromate, but systems without ozone are not required to perform this monitoring. Systems that use ozone and that also add sodium hypochlorite will need to closely monitor the quality of these sodium hypochlorite products for bromate content.

### *Chlorite*

Similar to bromate, chlorite monitoring is required only for systems using chlorine dioxide as an oxidant or disinfectant. Chlorite is a degradation product of chlorine dioxide. Chlorate is also a degradation product of chlorine dioxide but is not currently regulated. Chlorite and chlorate are potential degradation products of sodium hypochlorite, but systems using sodium hypochlorite are not required to monitor for chlorite unless they also use chlorine dioxide.

**Table 1-3 Target pH values for coagulation when TOC removal rates are not sufficient**

| Alkalinity | pH Value |
|---|---|
| 0–60 | 5.5 |
| >60–120 | 6.3 |
| >120–240 | 7.0 |
| >240 | 7.5 |

Monitoring for chlorite is more complicated than for bromate because chlorine dioxide will degrade and chlorite formation will increase over time. Therefore, chlorite monitoring requirements include daily monitoring at the distribution system entry point and monthly samples at three locations in the distribution system (first customer, average residence time, maximum residence time). Unlike the health risks for bromate, TTHM, and HAA5, the risk for chlorite requires compliance based on average of the three chlorite-monitoring locations each month. The Stage 1 DBPR MCL for chlorite is 1.0 mg/L.

### *Residual Disinfectants*

The maximum residual disinfectant level (MRDL) for combined or total chlorine is 4.0 mg/L as $Cl_2$. These are based on the same data used to monitor minimum free and combined chlorine levels in the distribution system as required by the SWTR, using the same monitoring locations used for the TCR. Chlorine dioxide residual also has an MRDL of 0.8 mg/L as $ClO_2$, based on daily samples at the treatment plant.

## Surface Water Treatment Rule

### *IESWTR and LT1ESWTR*

The goal of the IESWTR is to limit human exposure with harmful organisms, including *Cryptosporidium*, by promoting achievement of particle and turbidity removal targets for surface water treatment systems. Among IESWTR requirements that apply to surface water treatment plants are the following:

- Combined filter effluent turbidity must be ≤0.3 ntu for 95 percent of samples collected each month, including none with >1 ntu (compliance based on combined filter effluent samples collected at four-hour intervals during entire month).
- Utility must monitor each individual filter for turbidity at 15-minute intervals and must report results, including a filter profile (graphical representation of filter performance), if either of the following two conditions are met: (1) turbidity in any filter for two consecutive 15-minute intervals exceeds 1 ntu or (2) turbidity during first four hours of a given filter run exceeds 0.5 ntu for two consecutive 15-minute samples. Results must be reported within 10 days of the end of the month.
- Any newly constructed finished water reservoirs must include covers to keep out dust, debris, birds, etc.
- Utility must complete sanitary survey every three years. Existing surveys conducted after December 1995 can be used if they meet minimum requirements. Variances can be granted to decrease frequency to five years. The IESWTR explicitly requires that sanitary surveys include efforts to evaluate and control *Cryptosporidium*, in addition to other target organisms.

- Systems where the average of quarterly TTHM or HAA5 values exceeds 64 and 48 µg/L, respectively, need to complete disinfection profiling and benchmarking. *Profiling* involves determination of $C \times T$ values for each segment of treatment plant (see later discussion). *Benchmarking* involves determining lowest monthly average during 12-month monitoring of *Giardia* and virus inactivation. This procedure is required for any systems that are considering a major change to their disinfection practice. Consultation with the primacy agency is also required before any disinfection change.
- Turbidity monitoring records must be maintained for a minimum of three years.

Facilities in compliance with these requirements, chiefly the turbidity monitoring provisions, are designated by the IESWTR to have provided 2-log virus removal, 2.5-log *Giardia* removal, and 2-log *Cryptosporidium* removal. Literature and other information cited in the IESWTR final rule indicate that these credits are conservative, and most facilities meeting these requirements are probably achieving far greater levels of virus, *Giardia*, and *Cryptosporidium* removal than the minimum credits previously cited. The level of *Cryptosporidium* protection cited is sufficient to meet all requirements of the IESWTR, but the rule requires a total of 3.0 credits for *Giardia* and 4.0 credits for viruses. The additional credits (0.5-log for *Giardia* and 2-log for viruses) are required to be achieved by disinfection with free chlorine, chloramines, ozone, or chlorine dioxide by meeting *CT* requirements described later in this chapter.

Provisions of the IESWTR apply to large systems (>10,000 persons) using surface water sources. However, similar provisions are applied to smaller surface water systems (<10,000 persons), as outlined in the LT1ESWTR. The objectives of the LT1ESWTR and IESWTR are identical, though some of the compliance deadlines and other regulatory provisions are slightly different based on greater financial and personnel resources for larger systems.

### *Sanitary Surveys*

Sanitary surveys are a requirement of the Interim Enhanced Surface Water Treatment Rule (IESWTR). A sanitary survey is "an onsite review of the water source, facilities, equipment, operation, and maintenance of the public water system for the purpose of evaluating the adequacy of such source, facilities, equipment, operation, and maintenance for producing and distributing safe drinking water." Surveys are usually performed by the state primacy agency and are required of all surface water systems and groundwater systems under the direct influence of surface water.

These surveys are typically divided into eight main sections, although some state primacy groups may have more.

1. Water sources
2. Water treatment process
3. Water supply pumps and pumping facilities

4. Storage facilities
5. Distribution systems
6. Monitoring, reporting, and data verification
7. Water system management and operations
8. Operator compliance with state requirements

Sanitary surveys are required on a periodic basis usually every three years. Surveys may be comprehensive or focused according to the regulatory agency requirements.

### *CT Requirements*

Every water system that uses surface water as a source must meet treatment technique requirements for the removal and/or inactivation of *Giardia*, viruses, *Legionella*, and other bacteria. Because these pathogens are not easily identified in the laboratory on a routine basis, USEPA has set quality goals in lieu of MCLs in this instance. Meeting SWTR treatment technique goals demonstrates all or part of the required microbial protection, as previously noted, but additional protection is required through the use of approved disinfection treatment chemicals. The effectiveness of disinfection depends on the type of disinfectant chemical used, the residual concentration, the amount of time the disinfectant is in contact with the water, the water temperature, and, when chlorine is used, the pH of the water.

According to USEPA, a combination of the residual concentration, *C*, of a disinfectant (in milligrams per liter) multiplied by the contact time, *T* (in minutes), can be used as a measure of the disinfectant's effectiveness in killing or inactivating microorganisms. For water plant operators, this means that high residuals held for a short amount of time or low residuals held for a long period of time will produce similar results. Water plants are required to provide this computation daily, and it must always be higher than the required minimum value.

## LT2ESWTR

The Long-Term 2 Enhanced SWTR (LT2ESWTR) supplements SWTR requirements contained in the IESWTR for large surface water systems (>10,000 persons) and the Long-Term 1 Enhanced SWTR (LT1ESWTR) for small systems (<10,000 persons). Details of the rules can be reviewed in the *Federal Register* or at the USEPA website (http://water.epa.gov/drink/index.cfm). One of the key elements of the LT2ESWTR was the use of *Cryptosporidium* monitoring results to classify surface water sources into one of four USEPA-defined risk levels called "bins." Facilities in the lowest bin (bin 1) are required to maintain compliance with the current IESWTR. Facilities in higher bins (bins 2 to 4) are required to either (1) provide additional *Cryptosporidium* protection from new facilities or programs not currently in use at a facility or (2) demonstrate greater *Cryptosporidium* protection capabilities of existing facilities and programs using a group of USEPA-approved treatment technologies, watershed programs, and demonstration studies, referred to collectively as the *Microbial Toolbox*.

Implementation of the LT2ESWTR was phased over many years according to system size. Four separate size categories were established (schedules 1–4 with 4 being the smallest <10,000 population) for implementing the rule. The rule for schedule-4 systems allows filtered supplies to perform initial monitoring for fecal coliform to determine if *Cryptosporidium* monitoring is required.

## Filter Backwash Recycle Rule (FBRR)

The FBRR currently applies to systems of all sizes and is intended to help utilities minimize potential health risks associated with recycle, particularly associated with respect to *Giardia* and *Cryptosporidium*. Other contaminants of concern in the recycle stream include suspended solids (turbidity), dissolved metals (especially iron and manganese), and dissolved organic carbon. Plants that control recycle will also help minimize operational problems.

Prior to the FBRR, no USEPA regulation governed recycle. Regulations within the United States regarding recycle had been established by the states, if at all. State regulatory approaches varied from a requirement of equalization of two backwashes in Illinois to 80 percent solids removal prior to recycle and maintaining recycle flows at less than 10 percent of raw water flow in California. Virginia discourages recycling.

Key components of the FBRR include (1) recycle must reenter the treatment process *prior* to primary coagulant addition, (2) direct filtration plants must report their recycle practices to the state and may need to treat their recycle streams, and (3) a self-assessment must be done at those plants that use direct recycle (i.e., no separate equalization and/or treatment of recycle stream) and that operate fewer than 20 filters. The goal of the self-assessment is to determine if the design capacity of the plant is exceeded due to recycle practices.

## GWR

The USEPA promulgated the final Ground Water Rule (GWR) in October 2006 to reduce the risk of exposure to fecal contamination that may be present in public water systems that use groundwater sources. The rule establishes a risk-targeted strategy to identify groundwater systems that are at high risk for fecal contamination. The GWR also specifies when corrective action (which may include disinfection) is required to protect consumers who receive water from groundwater systems from bacteria and viruses.

A sanitary survey is required, by the state primacy agency, at regular intervals depending on the condition of the water system as determined in the initial survey. Systems found to be at high risk for fecal contamination are required to provide 4-log inactivation of viruses. Increased monitoring for fecal contamination indicators may be required by the regulatory authority.

## TCR and RTCR

The Total Coliform Rule (TCR) was finalized in 1989. The objective of the TCR is to promote routine surveillance of distribution system water quality to search for contamination from fecal matter and/or disease-causing bacteria. All points in a distribution system cannot be monitored, and complete absence of fecal matter and disease-causing bacteria cannot be ensured. The TCR is a regulatory approach for the implementation of monitoring programs sufficient to verify that public health is being protected as much as possible, as well as allowing utilities to identify any potential contamination problems in their distribution system. The rule requires monthly sampling at each distribution sampling point.

If a routine monthly sample is total coliform (TC) positive, the utility must determine fecal coliform (FC) or *Escherichia coli* (EC) in the same sample and also must perform verification monitoring by collecting a second sample and reanalyzing TC and FC/EC within 24 hours. The system is not in compliance if either of the following occurs: (1) if analysis and reanalysis of a given sampling location are TC positive (TC[+]) both times and FC[/EC+] at least one of these times or (2) if more than 5 percent of all monthly samples for a 12-month period are TC[+].

The TCR, and the Revised Total Coliform Rule (RTCR) that was finalized in 2013, impact all systems. The RTCR requires public water systems that are vulnerable to microbial contamination to identify and fix problems. The RTCR also established criteria for systems to qualify for and stay on reduced monitoring, thereby providing incentives for improved water system operation.

The RTCR also changed monitoring frequencies for some systems. It links monitoring frequency to water quality and system performance and provides criteria that well-operated small systems must meet to qualify and stay on reduced monitoring. It also requires increased monitoring for high-risk small systems with unacceptable compliance history and establishes some new monitoring requirements for seasonal systems such as state and national parks.

The RTCR rule further establishes an MCLG and an MCL for *E. coli* and eliminated the MCLG and MCL for total coliform, replacing it with a treatment technique for coliform that requires assessment and corrective action. The rule establishes an MCLG and an MCL of zero for *E. coli*, a more specific indicator of fecal contamination and potentially harmful pathogens than total coliform. USEPA has removed the MCLG and MCL of zero for total coliform. Many of the organisms detected by total coliform methods are not of fecal origin and do not have any direct public health implication.

Under the treatment technique for coliform, total coliform serves as an indicator of a potential pathway of contamination into the distribution system. A PWS that exceeds a specified frequency of total coliform occurrence must conduct an assessment to determine if any sanitary defects exist and, if found, correct them. In addition a PWS that incurs an *E. coli* MCL violation must conduct an assessment and correct any sanitary defects found.

The rule eliminated monthly public notification requirements based only on the presence of total coliforms. Total coliforms in the distribution system may indicate a potential pathway for contamination but in and of themselves do not indicate a health threat. Instead, the rule requires public notification when an *E. coli* MCL violation occurs, indicating a potential health threat, or when a PWS fails to conduct the required assessment and corrective action.

## Lead and Copper Rule

### *Regulation*

The objective of the Lead and Copper Rule (LCR) is to control corrosiveness of the finished water in drinking water distribution systems to limit the amount of lead (Pb) and copper (Cu) that may be leached from certain metal pipes and fittings in the distribution system. Of particular concern are pipes and fittings connecting the household tap to the distribution system service line at individual homes or businesses, especially because water can remain stagnant in these service lines for long periods of time, increasing the potential to leach Pb, Cu, and other metals. Although the utility is not responsible for maintaining and/or replacing these household connections, they are responsible for controlling pH and corrosiveness of the water delivered to the consumers.

Details of the LCR include the following:

- The LCR became effective Dec. 7, 1992.
- The action level for Pb is 0.015 mg/L and for Cu is 1.3 mg/L.
- A utility is in compliance at each sampling event (frequency discussed below) when <10 percent of the distribution system samples are above the action levels for Pb and Cu (i.e., 90th percentile value for sampling event must be below action level).
- Utilities found not to be in compliance must modify water treatment until they are in compliance. The term *action level* is used rather than *MCL* because noncompliance (i.e., exceeding an action level) triggers a need for modifications in treatment.

After identifying sampling locations and determining initial tap water Pb and Cu levels at each of these locations, utilities must also monitor other water quality parameters (WQPs) at these same locations as needed to monitor and evaluate corrosion control characteristics of treated water. The only exemptions from analysis of these WQPs are systems serving less than 50,000 people for which Pb and Cu levels in initial samples are below action levels.

Pb, Cu, and WQPs are initially collected at 6-month intervals, and then this frequency can be reduced if action levels are not exceeded and optimal water treatment is maintained. Systems that are in noncompliance and are performing additional corrosion-control activities must continue to monitor at six-month intervals, plus they must collect WQPs from distribution system entry points every two weeks.

Each utility must complete a survey and evaluate materials that comprise their distribution system, in addition to using other available information, to target homes that are at high risk for Pb/Cu contamination.

Revisions to the Lead and Copper Rule were enacted in 2007. These clarifications to the existing rule were made in seven areas:

- Minimum number of samples required
- Definitions for compliance and monitoring periods
- Reduced monitoring criteria
- Consumer notice of lead tap water monitoring results
- Advanced notification and approval of long-term treatment changes
- Public education requirements
- Reevaluation of lead service lines

Consult your local regulatory agency for those revisions that are applicable to your system.

## Phase I, II, and V Contaminants

### *Regulations*

The Phase I, II, and V regulations were finalized in 1989, 1992, and 1995, respectively, and include various inorganic and organic contaminants. Sampling and reporting frequency vary with constituent, though sampling is typically required once every three years after the initial sampling period. Variances or waivers are possible for a number of constituents based on analytical results and/or a vulnerability assessment.

## Public Notification Rule

USEPA has implemented a regulation called the *Public Notification Rule*. This rule is separate from the Consumer Confidence Report (CCR) Rule. The Public Notification Rule includes requirements for reporting certain water quality monitoring violations and other water quality incidents, as well as requirements for the timing, distribution, and language of the public notices. For example, the Public Notification Rule includes requirements that some incidents be reported within 24 hours, others within 30 days, and others included as part of the annual CCR. Some of these reporting requirements are more stringent than those currently required by USEPA. The regulation also includes requirements regarding how notices are to be distributed/broadcast (i.e., TV, radio, newspaper, hand delivery, regular mail, etc.), the format of the notices, the wording of certain items in the notice, and the need to include information in languages other than English.

Public notification according to the rule might include:

- Templates, or model notices, to be available for adaptation for certain potential incidents.
- Consolidated and updated lists of phone numbers and contacts for government (local, county, state), regulatory agencies, hospitals, radio and TV, newspapers, etc., that should be contacted per requirements of the Public Notification Rule.
- Checklists and flow diagrams outlining activities that would need to be completed for certain potential events outlined in the regulation.
- Identification of key personnel and what their roles and responsibilities would be to respond as required by the regulation.
- A plan to periodically review and update all lists, templates, and other aspects of a response plan every year or when/if the Public Notification Rule is modified by future federal or state regulations.

## Unregulated Contaminant Monitoring Rule

The 1996 amendments to the SDWA require USEPA to establish criteria for a monitoring program for currently unregulated contaminants to generate data that USEPA can use to evaluate and prioritize contaminants that could potentially be regulated in the future. USEPA has developed three cycles of the Unregulated Contaminant Monitoring Rule (UCMR):

1. UMCR1 in 1999
2. UMCR2 in 2007
3. UCMR3 in 2012

Failing to (1) perform required sampling and analysis, (2) use the appropriate analytical procedures, or (3) report these results are violations of the UCMR. However, the numerical results of these analytical efforts cannot result in a violation because none of the constituents in the UCMR are currently regulated (i.e., no MCLs, action levels, or other standards apply).

Although the UCMR contaminants have no standards associated with them, the data from this monitoring will need to be reported in the annual CCR. Therefore, the CCR will need to address implications of any constituents found above detection limits. Reporting UCMR results in the CCR would also fulfill the notification requirements for “unregulated contaminants” included in the recently promulgated Public Notification Rule.

Note that the UCMR is an ongoing part of the regulatory development process that will be repeated every five years. Utilities will be performing similar mandatory sampling for a new list of constituents every five years.

The third Unregulated Contaminant Monitoring Rule (UCMR3) was signed by USEPA Administrator Lisa P. Jackson on April 16, 2012. As finalized, UCMR3 will require monitoring for 30 contaminants using USEPA and/or consensus organization analytical methods during 2013-2015. Together USEPA, states, laboratories, and public water systems (PWSs) will participate in UCMR3.

## Operator Certification

Amendments to the 1996 SDWA required USEPA to develop national guidance for operator certification. The final rule was published on Feb. 5, 1999, and became effective on Feb. 5, 2001. State operator certification programs were required to address nine baseline standards, including operator qualifications, certification renewal, and program review. Indirect impacts of the rule on most water utilities include availability of Drinking Water State Revolving Fund (DWSRF) money and perhaps some slight modifications in paperwork/record-keeping requirements.

## Arsenic

The MCL for arsenic was reduced from 50 µg/L to 10 µg/L in the *Federal Register* published on Jan. 22, 2001. This was the second time USEPA has established an MCL that was higher than the technically feasible level (3 µg/L), with the first being the uranium rule in 2000. The original SDWA required the MCL to be set as close to the health goal (zero for arsenic and all other suspected carcinogens) as technically feasible. Amendments to the SDWA allowed USEPA the discretion to set the MCL above the technically feasible level.

The final rule, including the revised MCL, became effective three years after the rule was published.

## Radionuclides Rule

The Radionuclide Rule was published in December 2000. In the final rule, USEPA maintained the gross alpha MCL at 15 pCi/L MCL, 4 mrem/yr for beta emitters, 4 mrem/yr for photon emitters, and 5 pCi/L for combined radium 226 and 228 isotopes, and an MCL for uranium of 30 µg/L.

## Analytical Methods

Each of the individual USEPA regulations contains their own information regarding analytical methods approved for compliance monitoring. These and other approved analytical methods are compiled in a final rule titled "Analytical Methods for Chemical and Microbiological Contaminants and Revisions to Laboratory Certification Requirements" published Dec. 1, 1999. These analytical methods were approved for compliance monitoring effective Jan. 3, 2000. The USEPA-approved methods include analytical procedures developed by USEPA, plus procedures developed by others that USEPA endorses, including specific procedures developed by the American Society for Testing and Materials (ASTM) and some specific procedures included in *Standard Methods for the Examination of Water and Wastewater*, published jointly by the American Public Health Association (APHA), AWWA, and the Water Environment Federation (WEF).

Currently, only approved analytical methods can be used for compliance monitoring. In the future, USEPA hopes to implement a performance-based measurement system that will allow utilities to use alternative screening methods instead of requiring only USEPA-approved reference methods. The 1996 SDWA Amendments require USEPA to review new analytical methods that may be used for the screening and analysis of regulated contaminants. After this review, USEPA may approve methods that may be more accurate or cost-effective than established methods for compliance monitoring. These screening methods are expected to provide flexibility in compliance monitoring and may be better and/or faster than existing analytical methods.

The approval of new drinking water analytical methods can be announced through an expedited process in the *Federal Register*. This allows laboratories and water systems more timely access to new alternative testing methods than the traditional rulemaking process. If alternate test procedures have the same or better performance of the approved methods, they can be considered for approval using the expedited process.

## OPERATIONAL VIEWS OF CERTAIN CONTAMINANTS

### Turbidity

Turbidity is the measure of the amount of particulate material in water. It is measured by detecting the amount of light scattered by the particles in a water sample. Turbidity is used as an indicator of water quality and as an indicator of the efficiency of certain removal processes such as coagulation and filtration. Adequate removal of turbidity is an important step in the process of removing pathogens. Although the turbidity measurement provides no information about the nature of the particles it measures, turbidity is considered very important and is thus regulated as a treatment technique. Optimization efforts, such as those found in the Partnership for Safe Water, are designed around the optimization of turbidity removal. High turbidity levels can make the disinfection process less efficient by creating higher disinfectant demand. Higher turbidities may also protect coliforms from disinfection by absorbing or encasing them.

Pathogen passage can be related to turbidity events (spiking) in the finished water. The minimization of the frequency and magnitude of spiking should be a top priority in water treatment. Operators should view any event of individual filter turbidity spiking as a potential for the passage of harmful pathogens into the water column. Each event should be analyzed for cause, and a plan for the elimination of the cause(s) should be implemented. Most filter-spiking events can be traced to operator involvement, unless plant inadequacies exist that make it impossible for water to be treated at times.

### TOC

TOC is a composite measure of the organic content of the water. It is important for water suppliers to measure this contaminant because its presence and amount correlate to the production of DBPs. TOC can be removed in the coagulation/settling/filtration process, and removal efficiencies for this contaminant are regulated.

The challenge for treatment plant operators is to strike a balance between removal of TOC with traditional pH-lowering methods (more coagulant, more acid) and the need to maintain compliance levels with the LCR. Also, site-specific requirements for residuals disposal can be affected by the use of more coagulant for TOC removal. Especially difficult are the choices that operators consider when, although they are in compliance with DBP MCLs, they know they can achieve better results with more TOC removal through addition of more coagulant.

## Waterborne Pathogens

Disease-causing organisms, called *pathogens*, include all of the problem-causing bacteria, viruses, protozoa, and algae. Well-known diseases caused by these organisms include typhoid fever, cholera, Legionnaires' disease, peptic ulcers, hepatitis, giardiasis, cryptosporidiosis, gastroenteritis—the list goes on. All of these pathogens can be found in natural surface water supplies and therefore can invade the treated water supply in sufficient numbers that will cause disease in the consumer. Even groundwater supplies may come under the influence of surface water and therefore be contaminated. Typically, pathogen exposure presents an acute risk rather than a chronic risk, and the detected presence of them or their surrogates will bring on boil-water notices. Given that some consumers are temporarily or permanently less immune than other consumers, pathogen removal is among the most important tasks confronting the water plant operator.

Bacteria, which are organisms that can cause severe illness in people, are usually minimized by conventional water treatment processes. They can exist in wide variations of temperature and water quality ranges, and some bacteria can pass through the water treatment plant and find their way to the consumer in small numbers. *Legionella* is such an example of an organism that can occur in the finished waters of systems employing full treatment. Of particular interest to water plant operators is the group of bacteria called *coliforms*. These organisms are used as indicator bacteria because they are easily cultured in the laboratory and can be an indicator of the presence of other more-difficult-to-culture bacteria.

Viruses, which are smaller organisms than bacteria, can also cause a number of debilitating diseases, including hepatitis and polio. They are difficult to culture, even in the most sophisticated laboratories. Fortunately, most viruses are removed or inactivated by conventional water treatment practices. The lime-softening process is very effective against viruses because of the high pH employed, and maintaining proper *CT* values improves disinfection of viruses.

Protozoa are larger than bacteria and can be very resistant to disinfection because of their ability to form spores or cysts that have tough outer casings. The notable protozoa that water plant operators deal with are *Giardia* and *Cryptosporidium*. These two organisms are found in nature and are typically removed in the filtration process. *Giardia* can be inactivated by sufficient $C \times T$ values employing chlorine, but *Cryptosporidium* is considered to be resistant to chlorine at levels far greater than those typically used in water treatment plants. The IESWTR regulates these two organisms (see text in this chapter) by requiring treatment techniques. When the treatment techniques are met, the utility is given "credit" for removal of *Cryptosporidium* and removal/inactivation of the *Giardia*. This credit must be achieved continually as the plant operates. Failure to meet the treatment technique results in boil-water notices.

Algae do not typically pose a health concern for humans, although some may produce neurotoxins and hepatoxins that can be of concern. The more frequent problems caused by algae are taste-and-odor episodes and filter-clogging episodes. Algae are difficult to coagulate and filter, and it is common for them to pass through filters in high numbers. Because of this, it is often more practical to prevent algae from growing than it is to remove them once they are in the plant.

## Inorganic Chemical Contaminants

The inorganic chemical contaminants found in water supplies may be found as naturally occurring in the source or they may appear in the water through contact with the piping and storage components of the system. The chemical treatment process can also add to inorganic contamination. These chemicals in water can present chronic health problems at low levels and can also cause acute distress when ingested in high doses.

Many inorganic chemical contaminants have MCLs associated with them. Of notable exception are lead and copper, which carry action levels, as explained previously in the chapter. Most are regulated at the entry point to the distribution system, again with lead and copper being the exception. Iron and manganese are of special interest to the operator because of the staining problems they can create on fixtures. Removal of these nuisance contaminants is detailed in chapters 4 and 10. Nitrates are regulated with an MCL of 10 mg/L because they are believed to cause problems with the circulatory systems of infants.

Fluoride (see chapter 10) is an inorganic constituent with an interesting role in the water treatment business. Its presence in water is required by most states and communities (there are exceptions), but it is also a regulated contaminant. Adding to the confusion is the fact that fluoride carries with it both an MCL and an SMCL. The water plant operator, therefore, is confronted with the problem of adding a regulated contaminant to the water and then carefully controlling the amount that is added. The MCL for fluoride is 4.0 mg/L, and the SMCL is 2.0 mg/L. High levels of fluoride can cause mottling of the enamel of the teeth. Still higher levels can be poisonous to humans.

### DBPs

Chlorine has played the primary role in disinfection of PWSs, but chlorine dioxide, ozone, and chloramines are also used. The use of these disinfectants can cause the formation of DBPs, as previously discussed. A number of these by-products are probably carcinogens and may cause other toxic effects. The rules governing the limitation of the DBPs set limits based on chronic exposure and tend to be regulated as averages for occurrence. The challenge for operators is to maintain adequate disinfection levels for microbiological protection while providing a water that is low in the by-products created in the disinfection process.

Chief among the DBPs (where chlorination is used) is the occurrence of THMs (see chapter 8), but the HAAs are also currently regulated. In time, other DBPs are expected to be regulated as health-effects data are brought forth.

When ozone is used as a primary disinfectant, there are potential concerns with bromate and formaldehyde production.

## REGULATORY CHANGES

There is no doubt that regulations will continue to change based on results of research and a better understanding of the health consequences of various contaminants. Water plant operators must keep abreast of the latest developments and be prepared to adjust to these regulations. Water system operators will occasionally be presented with a dilemma when new research indicates that an unregulated contaminant may be harmful and it is found (perhaps in a very low concentration) in their water supply. What should the water utility tell its customers about this situation? Each utility should develop a communications plan and have it ready for this almost inevitable circumstance.

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