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Committee Report: Disinfection at small systems

A survey of smaller water systems' disinfection practices looks at strengths and potential pitfalls in light of upcoming drinking water regulations.

AWWA Water Quality Division Disinfection Systems Committee

In 1998, the Disinfection Systems Committee of AWWA's Water Quality Division surveyed the disinfection practices of smaller US water systems (serving 10,000 or fewer people). Systems using groundwater and those using surface water were surveyed separately. Of survey respondents, 97 percent of surface water systems and 86 percent of groundwater systems provided disinfection. Among surface water systems responding, 94 percent provided filtration. Survey data suggest that most systems will be able to comply with Stage 1 Disinfectants/Disinfection By-products Rule requirements for total trihalomethanes, but many may need to better control haloacetic acids. This report suggests that systems currently using disinfection should begin disinfectant and disinfection by-product monitoring and develop disinfection profiles ahead of regulatory requirements.

Periodically the Disinfection Systems Committee of the AWWA Water Quality Division has surveyed water utilities in the United States and reported on their disinfection treatment practices.[1–3] For the most part, results were considered in relation to regulatory requirements current at the time of the individual survey and the regulations' effect on larger, surface water systems. Small systems represented only a slight portion of previous survey respondents, and no similar studies have focused solely on smaller drinking water systems.

For executive summary, see page 154.

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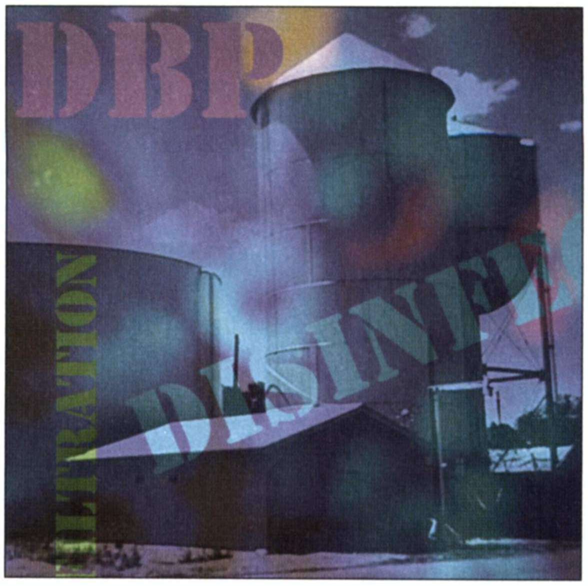
Small systems must adjust to the regulatory climate

Smaller drinking water systems using surface water and groundwater sources will soon have to comply with a number of new National Primary Drinking Water Regulations (NPDWRs). These include the Stage 1 Disinfectants/Disinfection By-products (D/DBP) Rule, the Long-term 1 Enhanced Surface Water Treatment Rule (LT1ESWTR), the Ground Water Rule (GWR), and regulations for arsenic (As) and radon (Rn).[4,5] All will have at least some effect on disinfection practices.



Smaller drinking water systems using surface water and groundwater sources will soon have to comply with a number of new National Primary Drinking Water Regulations.

The Stage 1 D/DBP Rule was promulgated by the US Environmental Protection Agency (USEPA) in December 1998.[4] It sets specific monitoring requirements, maximum residual disinfectant levels for chlorine, chloramine, and chlorine dioxide, and maximum contaminant levels (MCLs) for certain DBPs. For systems using surface water and conventional filtration, enhanced coagulation is also required as a treatment technique to control DBP precursors. Beginning in December 2003, these requirements will apply to all community and nontransient–noncommunity public water supply systems that serve fewer than 10,000 people and use a chemical disinfectant. Because current total trihalomethane (TTHM) monitoring and MCL requirements do not apply to systems serving fewer than 10,000 people,[6] many small systems and their regulatory agencies may be unprepared for the problems and actions arising from the D/DBP Rule.

The LT1ESWTR was proposed in April 2000 and is expected to be promulgated late in the year. Enforcement of the rule will begin three years after promulgation. The LT1ESWTR will apply to surface water systems serving fewer than 10,000 people. Its proposed requirements are very similar to those in the Interim ESWTR,[7] which generally applies to systems serving 10,000 or more people. The LT1ESWTR will require smaller systems to perform a profile of disinfection based on disinfectant concentration multiplied by contact time ($C \times T$) calculations and will impose filter monitoring and performance requirements based on turbidity. Turbidity concentrations in excess of the MCL would trigger followup activities.

The GWR is in its last stages of development. It is expected to be proposed in May 2000 and finalized late in 2000; enforcement would begin three years after promulgation. In its current form, the GWR will require sanitary surveys and correction of significant deficiencies, source water monitoring for certain systems based on hydrogeological characteristics of the well, and treatment based on monitoring results. Although disinfection will not be directly mandated, systems that cannot provide adequate protection of sources and distribution through other means must provide disinfection. Those systems that do disinfect may have to meet somewhat reduced requirements.

The NPDWR for Rn was proposed in November 1999 and is anticipated to be promulgated in August 2000.[5] The NPDWR for As is expected to be proposed in mid-2000 and is expected to be promulgated by January 1, 2001. Depending on monitoring results and other activities, some systems may have to install disinfection systems or modify existing disinfection practices in order to achieve compliance with these rules. For example, systems treating for Rn by air-stripping would have to provide some form of disinfection, because the system would be open to airborne contamination. Several technologies for As removal require preoxidation of As+3 to As+5, which can be provided by chlorine or ozone. The As regulation in particular may have a major effect on small groundwater systems. If the As MCL is established at 5 or 10 µg/L, perhaps as many as 10 percent of all community groundwater systems will require treatment. If chlorine or ozone is used as an oxidant, Stage 1 of the D/DBP Rule would require that systems pay attention to DBP concentrations, regardless of the oxidation levels necessary or achieved.

As important and immediate as it may be for utilities and regulatory agencies, compliance with drinking water regulations is only a means to the end of producing safe drinking water for the public. In some cases, current regulations may not be as protective as

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TABLE 1 **Disinfectants used by groundwater system respondents**

Type of Disinfectant	Systems Using Disinfectant *percent*
Chlorine gas	61
Sodium hypochlorite	34
Bulk	31
On-site generated	3.3
Calcium hypochlorite	4.5
Powder	1.7
Tablet	2.8
Other*	3.9

*Includes permanganate and low concentrations of liquid bleach

necessary to achieve this goal. Thus, if utilities accept their responsibility to provide safe drinking water, they must implement the necessary disinfection practices, irrespective of regulatory requirements. For example, estimates of unaddressed microbiological contamination in groundwater systems suggest it may be responsible for up to several million illnesses a year.[8] This may indicate a need for systems to initiate proactive disinfection, even though it may not be specifically required by regulation.

Before implementation of these new regulations and the changes they may bring, the Disinfection Systems Committee decided to survey smaller systems (serving fewer than 10,000 people) in order to obtain a better picture of their current disinfection treatment practices. By detailing disinfection practices already in use, survey responses could help track the effect of new regulations and determine the best ways to address regulatory implementation. Utilities, regulatory agencies, and others concerned about adequate public health protection could also use survey results to evaluate drinking water risks beyond those currently addressed by regulations.

An understanding of the appropriate water quality parameters is essential to proper design and construction of systems that can simultaneously comply with these regulations.

AWWA surveys disinfection practices of smaller systems

In 1998–99, the Disinfection Systems Committee distributed two surveys specifically developed for utilities serving 10,000 or fewer people.

One survey addressed systems using groundwater and included questions on treatment practices and disinfection. Because these systems have generally not had to comply with the TTHM MCL, the survey did not include questions on source water quality or DBP monitoring results. A total of 1,421 surveys were mailed to utilities identified from the WaterStats database. Surveys were sent to 771 systems serving 501–1,000 people, 400 systems serving 1,001–3,300 people, and 250 systems serving 3,301–10,000 people. Surveys were completed and returned by 208 (15 percent) of the systems.

The second survey addressed surface water systems and included questions on treatment practices, including filtration and disinfection. Although these systems are generally not required to monitor for source water qualities, DBPs, or specific microbiological pathogens (such as *Giardia* or *Cryptosporidium*), the survey included questions about any such monitoring results. A total of 940 surveys were mailed to utilities identified from WaterStats. Surveys were sent to 364 systems serving 501–1,000 people, 326 systems serving 1,001–3,300 people, and 250 systems

TABLE 2 **Source water and average daily plant flow for small system respondents**

	System Size by Number of People Served *number of systems; average daily plant flow in mgd (m^3/d)*				
Water Source	**25–100**	**101–500**	**501–3,300**	**3,301–5,000**	**5,001–10,000**
River or stream	0	2; 0.2 (757)	24; 0.44 (1,665)	5; 1.7 (6,435)	10; 1.4 (5,300)
Lake or reservoir	1; 0.2 (757)	3; 0.094 (356)	37; 0.37 (1,400)	7; 0.64 (2,422)	18; 0.99 (3,747)
Purchased water	0	1; 0.082 (310)	2; 0.4 (1,514)	0	0
Groundwater under direct influence of surface water	0	0	6; 0.3 (1,136)	1; 0.86 (3,255)	1; 1.4 (5,300)
Total	1; 0.2 (757)	6; 0.094 (356)	69; 0.41 (1,552)	13; 1.2 (4,540)	29; 1.3 (4,920)

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serving 3,301–10,000 people. Surveys were completed and returned by 118 (12 percent) of the systems.

Groundwater system survey yields results in three categories. *System size.* Of the 208 surveys returned by small systems using groundwater, 200 provided adequate information on systems serving 10,000 or fewer people. These systems were classified according to size, using the categories currently specified by USEPA. Three systems (1.5 percent) served 25–100 people, 35 systems (18 percent) served 101–500 people, 124 systems (62 percent) served 501–3,300 people, and 38 systems (19 percent) served 3,301–10,000 people.

TABLE 3 Source water quality parameters for surface water system respondents

Parameter	Mean	Median	Minimum	Maximum
Annual maximum temperature—°F (°C)	73 (23)	75 (24)	24 (–4)	100 (38)
Annual minimum temperature—°F (°C)	41 (5)	39 (4)	4 (–15)	77 (25)
pH	7	7	5.4	9.4
Alkalinity—*mg/L as $CaCO_3$*	79	80	3	420
Hardness—*mg/L as $CaCO_3$*	114	107	3	650
Turbidity—*ntu*	9.7	3.5	0.02	2,500
Total organic carbon—*mg/L*	4.3	3.7	0.5	15
Total coliform bacteria—*organisms/100 mL*	14 (geometric mean)	3.5	0.02	3 million
Fecal coliform bacteria—*organisms/100 mL*	7.5	0	0	320

The percentage of systems of different size classes responding to the survey did not correspond to the size distribution of smaller systems reported by USEPA.[5] Agency data show 42,256 groundwater systems serving 10,000 or fewer people. Of these, USEPA reports that 14,232 (34 percent) serve 25–100 people, 15,070 (36 percent) serve 101–500 people, 10,465 (25 percent) serve 501–3,300 people, and 2,489 (6 percent) serve 3,301–10,000 people. Thus, relatively larger systems are overrepresented in AWWA survey results, a fact that must be accounted for in data interpretation.

Water source. Most systems (82 percent) used sources characterized as true groundwater. A smaller number (6.5 percent) used groundwater characterized as under the direct influence of surface water. A surprising number of systems (12 percent) over all size categories did not know whether their water was under the influence of surface water.

Wells per system. As might be expected, larger systems reported more wells. The smallest-size systems (serving 25–100 people) reported an average of 1.7 wells. Those serving 101–500 people averaged 2.0 wells, those serving 501–3,300 individuals averaged 2.8 wells, and those serving 3,301–10,000 people averaged 4.4 wells. These numbers are consistent with USEPA findings[5] of an average of 1.5 wells for systems serving 25–100 people, 2.0 wells for systems serving 101–500 people, 2.8 wells for systems serving 501–3,300 people, and 4.6 wells for systems serving 3,301–10,000 people.

Disinfection. AWWA groundwater survey respondents practiced disinfection at a substantially higher rate than reported by groundwater systems in general. Of the 200 respondents tallied, 172 systems (86 percent) disinfected the source water and provided a residual. Disinfection was practiced by all of the smallest systems (serving 25–100 people), 88 percent of systems serving 101–500 people, 81 percent of systems serving 501–3,300 people, and 97 percent of systems serving 3,301–10,000 people.

In contrast, USEPA data indicate only about 55 percent of all community groundwater systems provide disinfection.[9] Specifically, USEPA reported disinfection in place for 53 percent of systems serving 25–100 people, 77 percent of systems serving 101–500 people, 85 percent of systems serving 501–3,300 people, and 88 percent of systems serving 3,301–10,000 people.[5]

All respondents to the AWWA survey of smaller groundwater systems use some form of chlorine for disinfection (Table 1). No system reported the use of ozone or ultraviolet (UV) light as the disinfectant. One system used permanganate along with chlorine. Most of the systems that provided disinfection (61 percent) used chlorine gas. The others (40 percent) used one of several forms of hypochlorite, either as liquid or powder. Six systems (3 percent) used both gaseous chlorine and hypochlorite. Larger systems

TABLE 4 Treatment processes used by surface water system respondents

Treatment Process	Systems—*percent*
Filtration	97
Clearwell–finished water storage	94
Coagulation	85
Flocculation	76
Sedimentation	72
Mixing basin–rapid mix	65
Fluoridation	56
Corrosion control	52
Disinfection contact basin	50
Raw water storage–presedimentation	25
Preoxidation	18
Softening	11

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TABLE 5 Filtration treatment techniques used by surface water system respondents

Filtration Treatment	System Size by Number of People Served *number of systems* 25–100	101–500	501–3,300	3,301–5,000	5,001–10,000	Total number of systems *percent*
Rapid dual-media	0	1	25	7	15	48 (46)
Conventional rapid sand	0	1	22	3	9	35 (33)
Granular carbon cap on rapid dual-media or conventional rapid sand	0	0	12	2	7	21 (20)
Rapid tri-media	0	1	8	1	5	15 (14)
Slow sand	1	2	4	1	1	9 (9)
Granular carbon without any other filtration	0	0	2	0	0	2 (2)
Diatomaceous earth	0	0	1	0	0	1 (1)
Microfiltration	0	0	1	0	0	1 (1)

TABLE 6 Disinfection treatment used by surface water system respondents

Disinfection Treatment	System Size by Number of People Served *number of systems* 25–100	101–500	501–3,300	3,301–5,000	5,001–10,000	Total number of systems *percent*
Chlorine gas	0	4	50	11	24	89 (82)
Hypochlorite, all forms	1	3	20	1	3	28 (26)
Bulk sodium hypochlorite	0	2	12	0	2	16 (15)
On-site generated sodium hypochlorite	0	1	0	1	0	2 (2)
Calcium hypochlorite powder	1	0	8	0	1	10 (9)
Calcium hypochlorite tablets	0	0	0	0	0	0
Chlorine dioxide	0	0	3	1	3	7 (6)
Chloramines	0	0	0	0	2	2 (2)
Permanganate	0	1	0	0	0	1 (1)
Ozone	0	0	0	0	0	0
Ultraviolet light	0	0	0	0	0	0

tended to use chlorine gas rather than hypochlorite. All the systems serving 25–100 people and 58 percent of the systems serving 101–500 people used hypochlorite, but hypochlorite was used by only 46 percent of systems serving 501–3,300 people and 19 percent of systems serving 3,301–10,000 people. Most systems applied disinfection on a well-by-well basis.

Systems were surveyed for disinfectant dosages and residual levels at the entrance to their distribution systems. Reported disinfectant dosages averaged 1.6 mg/L as chlorine, with a range of 0.45–20.5 mg/L. Residual concentrations averaged 1.2 mg/L at the entrance to the distribution system, with a range of 0.3–7.5 mg/L.

Surface water systems provide data on water source and quality. ***System size.*** Of the 118 surveys returned by small systems using surface water, 109 provided adequate information on systems serving 10,000 or fewer people. Systems were classified according to size, using the categories specified by USEPA. One system (1 percent) served 100 people, six systems (5 percent) served 101–500 people, 65 systems (60 percent) served 501–3,300 people, 12 systems (11 percent) served 3,301–5,000 people, and 25 (23 percent) served 5,001–10,000 people.

Water source. Most systems (60 percent) reported lakes or reservoirs as their water source; rivers or streams were used by 38 percent. A few systems (7 percent) used groundwater under the direct influence of surface water. Three systems (2 percent) purchased their water. Most systems used a single water source; only nine (8 percent) used a second source, and one used more than two sources. Table 2 shows water source and plant flow for each size category of surface water system. Average daily plant flow increased with system size.

Source water quality. Most systems monitored raw water for temperature (72 percent), pH (85 per-

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cent), alkalinity (72 percent), turbidity (86 percent), and hardness (63 percent). Fewer systems monitored their source water for total and fecal coliform bacteria (23 percent) or total organic carbon (13 percent). Table 3 shows source water quality parameters for surface water systems. Only one or two systems monitored for heterotrophic bacteria or DBP precursors such as bromide, UV absorbance, or ammonia.

With respect to occurrence of total coliform bacteria, fecal coliform bacteria, or both in water sources, most systems providing these data (> 85 percent) did not detect any of these indicators. However, those systems that did detect total coliform bacteria, fecal coliform bacteria, or both in their water source reported an occurrence rate of essentially 100 percent of the time, indicating the possibility of compromised water sources.

TABLE 7 **Disinfection application points, dosage, and residual used by surface water system respondents**

Treatment Process	Systems *percent*	Free Chlorine Dosage *mg/L (average range)*	Residual *mg/L*
Raw water storage–resedimentation	3	ID*	ID
Preoxidation (predisinfection)	12	1.8 (0.2–5.0)	ID
Mixing basin–rapid mix	42	2.8 (0.5–5.9)	2.1
Coagulation	7	ID	ID
Flocculation	11	3.0 (0.4–5.0)	1.7
Sedimentation	8	ID	1.4
Filtration	25	2.2 (0.75–8.0)	1.4
Disinfection contact basin	12	3.1 (0.75–8.0)	2.6
Clearwell–finished water storage	75	2.0 (0.5–8.0)	1.7
Entry to distribution system	18	2.0 (0.1–8.0)	1.4

*ID—insufficient data

Treatment processes. Surface water systems were asked to report the different treatment processes in use. Almost all systems providing information on their water treatment processes at least met SWTR[10] requirements for filtration and disinfection. Table 4 shows the variety of treatment processes and the percentage of use by surface water systems.

The data present a snapshot of smaller community drinking water systems as more active and vigilant than they are generally pictured.

Filtration. Systems were asked to describe the type of filtration in place. Rapid dual-media filtration was the most popular approach, used by 46 percent of the systems. Conventional rapid sand filtration was used by 33 percent, rapid tri-media filtration was used by 14 percent, and slow sand filtration by 9 percent. An additional granular carbon cap was used by 20 percent. Table 5 lists filtration treatment techniques and the number of systems using each.

Disinfection practices. Among disinfectants used, chlorine gas was the clear favorite, used by 82 percent of reporting systems. Hypochlorite in its various forms was used by 26 percent of all systems, especially by systems serving 501–3,300 people. Chlorine dioxide was used by 7 percent. No system reported using ozone or UV light for disinfection. Several systems reported using more than one disinfectant; these multiple-disinfectant systems almost exclusively used chlorine gas and sodium hypochlorite in combination. Table 6 lists disinfection treatments and their use by surface water systems.

Systems reported an average of 1.7 disinfection application points. As shown in Table 7, the predominant site for disinfection was at the clearwell or finished water storage (75 percent of systems), followed by the mixing basin or rapid-mix site (42 percent).

Microbiological water quality. Beyond the required monitoring for total and fecal coliforms, very few systems reported data for either their source water or finished water for other microbiological contaminants such as viruses, *Giardia*, *Cryptosporidium*, or *Legionella*. Five systems monitored their source water for viruses; eight systems monitored their finished water for viruses. For *Giardia*, nine systems monitored their source water, and 16 monitored their finished water. For *Cryptosporidium*, five systems monitored their source water, and 13 monitored their finished water. For *Legionella*, three systems monitored their source water, and seven monitored their finished water. No system reported levels of microbiological contamination for any of these pathogens.

DBP concentrations in finished water quality. When systems were asked whether they measured certain DBPs in their finished water or distribution system, a wide range of responses was reported for the various by-products. Fifty-five systems (51 percent) monitored for THMs. Only seven to ten systems monitored for any of the haloacetic acids (HAAs). Only one or two

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TABLE 8 Trihalomethane (THM) concentrations reported by surface water system respondents

Disinfection Treatment	System Size by Number of People Served average µg/L (range)					All Systems average µg/L
	25–100	101–500	501–3,300	3,301–5,000	5,001–10,000	
Total THMs	100	43	50 (37–98)	51 (37–94)	49 (37–77)	51
Chloroform		42	46 (28–73)	36 (21–54)	31 (26–62)	39
Dichlorobromomethane		0	7 (7–11)	3 (3–5)	11 (8–11)	7
Chlorodibromomethane		1	1 (1–2)	3 (3–5)	2 (1–3)	2
Bromoform		0	3 (1–6)	0.5 (0–1)	0.7 (0.6–0.8)	2

systems monitored for bromate, chlorate, chlorite, chloral hydrate, chloropicrin, or haloacetonitriles.

The significant difference in THM monitoring versus HAA monitoring is likely attributable to specific state requirements for THM monitoring that include systems serving fewer than 10,000 people, whereas such monitoring is not required for these systems under the current federal TTHM regulations.[6] Table 8 shows THM data for surface water system respondents. Running annual average concentrations are well below both the current TTHM MCL of 100 µg/L and the Stage 1 D/DBP Rule MCL of 80 µg/L. Chloroform is the dominant species. Aggregate data for HAAs are shown in Table 9.

Utilities most likely to be affected by the regulations may want to consider instituting monitoring before the strict regulatory schedules take effect.

Survey data provide snapshot of smaller systems

In common with most such surveys, the AWWA disinfection surveys yielded many responses with confusing or inconsistent information. Because of this deficiency, data interpretations must be more qualitative than quantitative. Nevertheless, the data present a snapshot of smaller community drinking water systems as more active and vigilant than they are generally pictured.

Some groundwater systems offer high degree of disinfection. The high degree of disinfection currently practiced by the larger of the small-size systems is encouraging with respect to documented concerns about microbiological pathogens in groundwater. The choice of chlorine disinfection is also advantageous. Because viruses (the identified organisms of concern in groundwater) are sensitive to chlorine disinfection, these systems may be providing substantial health protection, even if they do not meet strict regulatory $C \times T$ criteria. Additionally, the oxidation provided by chlorine would be helpful in support of treatment techniques for As removal.

Although details of USEPA drinking water regulations for As have not been proposed, recent regulatory analyses suggest that a substantial number of groundwater systems not currently disinfecting will need to install oxidation treatment as part of their compliance with an As MCL. Depending on the choice of oxidant, these systems may then need to comply with Stage 1 D/DBP Rule requirements. An understanding of the appropriate water quality parameters is essential to

TABLE 9 Haloacetic acid concentrations reported by surface water system respondents

Haloacetic Acid	Finished Water* Average µg/L (range)	Distribution System† Average µg/L (range)
Total haloacetic acids	54 (41–75)	58
Monochloroacetic acid	2	3
Dichloroacetic acid	27 (24–30)	40 (28–51)
Trichloroacetic acid	20 (17–28)	36 (20–53)
Monobromoacetic acid	1	0
Dibromoacetic acid	0.9 (0.5–1.0)	0.5
Tribromoacetic acid	5	5
Bromochloroacetic acid	4 (3–4)	5

*Data from ten systems
†Data from four systems

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proper design and construction of systems that can simultaneously comply with these regulations.

The lack of source water quality and DBP data for the smaller groundwater systems is understandable but may cause concern as these systems attempt to achieve compliance by 2005. The utilities most likely to be affected by the regulations may want to consider instituting monitoring before the strict regulatory schedules take effect.

Most surface water systems use filtration, disinfection. Data provided by the small surface water systems indicate that virtually all systems have both filtration and disinfection in place, in accordance with SWTR requirements. Although the success of small surface water systems in complying with specific SWTR turbidity and log removal or inactivation requirements could not be determined from the survey, data suggest that existing systems will have to achieve optimization and better operation to comply with the LT1ESWTR.

The limited DBP data collected forestall forming conclusions, but the reported levels of THMs and HAAs suggest that most systems surveyed will not have significant problems complying with Stage 1 D/DBP Rule requirements. These systems will more likely focus their efforts on optimizing treatment based on water quality. The dominance of chloroform relative to other THMs is a noteworthy finding, particularly from a public health perspective. According to USEPA and others,[4,11] chloroform is unlikely to be problematic for public health even at concentrations substantially above the current TTHM MCL. Survey results indicated that other THMs are also well below levels of health concern.

The limited survey data for HAAs indicate most systems would be close to compliance with the Stage 1 D/DBP Rule HAA5 MCL of 60 µg/L, but the scarcity of adequate information on these contaminants remains a concern. Because HAA monitoring is not currently required, this lack of data was not unexpected. However, the absence of monitoring may be problematical for systems that must simultaneously comply with both TTHM and HAA5 requirements in 2003. Because THM and HAA formation are inversely related with respect to pH during disinfection with chlorine, current approaches to THM control to meet the MCL may have resulted in elevated HAA concentrations. Systems may find it advantageous to initiate HAA monitoring in advance of LT1ESWTR disinfection profiling and Stage 1 D/DBP Rule monitoring requirements.

At this time, the LTIESWTR does not require that systems conduct a disinfection profile to assess the total disinfection ($C \times T$) levels as outlined in the IESWTR. However, a prudent approach for systems considering operational changes would be to conduct such a profile before taking action.

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