Prepared as part of the National Water-Quality Assessment Program, Source Water-Quality Assessment

Organic Compounds Assessed in Chattahoochee River Water Used for Public Supply near Atlanta, Georgia, 2004–05

Organic compounds studied in a U.S. Geological Survey (USGS) assessment of water samples collected from the Chattahoochee River and from the City of Atlanta public supply system generally are manmade and include pesticides, solvents, gasoline hydrocarbons, personal-care and domestic-use products, refrigerants, and propellants. A total of 50 of the 266 compounds were detected at least once in source-water samples collected at the drinking-water intake for the City of Atlanta, one of several municipalities that rely on the Chattahoochee River for its water supply. The diversity of compounds detected reflects the range of contaminant sources upstream from Atlanta, including urban and agricultural runoff, treated wastewater outfalls, and groundwater discharge. Five compounds were detected year round in source water, including three herbicides commonly used on agricultural and urban lands, a disinfection by-product, and a gasoline hydrocarbon. About 70 percent of the 33 commonly detected compounds in source water (detected in at least 20 percent of all samples) also were detected in finished water (after treatment but prior to distribution). Concentrations for all of the detected compounds were less than human-health benchmarks, which are available for about one-half of the detected compounds.

Introduction

An investigation by the U.S. Geological Survey (USGS) National Water-Quality Assessment (NAWQA) Program characterized the occurrence of 266 organic compounds in source water and finished water from the Chattahoochee River, which is the main water-supply source for the Atlanta metropolitan area (fig. 1). Source water is stream water collected at a surface-water intake prior to water treatment, and finished water is water that has passed through treatment processes prior to distribution. Samples were collected approximately monthly during 2004–05 and included 15 paired source-water and finished-water samples. Samples were collected during winter-spring high flow and summer-fall low flow, but storm events were not targeted during this Source Water-Quality Assessment (SWQA) study. Samples were analyzed for pesticides and degradates, gasoline hydrocarbons, solvents, disinfection by-products, personal care and domestic-use products, and other organic compounds. Community water systems are required to monitor regulated organic compounds under the Safe Drinking Water Act of 1996 (U.S. Environmental Protection Agency, 1998); however, most compounds included in this study are not regulated by Federal drinking-water standards (U.S. Environmental Protection Agency, 2007a). The Chattahoochee River study is part of an ongoing NAWQA investigation of community water systems across the United States. Additional details about the national study are given in Carter and others (2007).

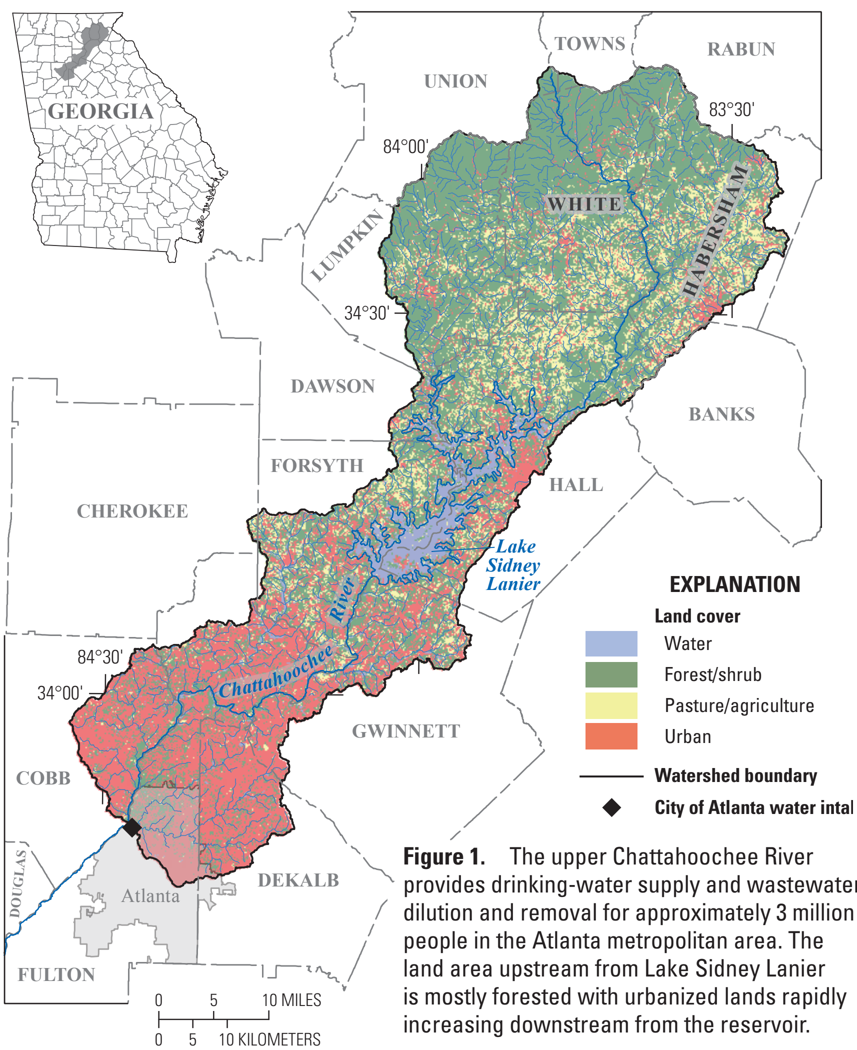

Figure 1. The upper Chattahoochee River provides drinking-water supply and wastewater dilution and removal for approximately 3 million people in the Atlanta metropolitan area. The land area upstream from Lake Sidney Lanier is mostly forested with urbanized lands rapidly increasing downstream from the reservoir.

Occurrence of Organic Compounds in Source Water

About one-fifth of the 266 compounds characterized were detected in at least one source-water sample; a few compounds were detected in nearly all samples. The detected compounds represent many different sources and uses and include pesticides, solvents, gasoline hydrocarbons, and personal-care products. Five compounds were detected year-round, including herbicide compounds commonly used in the Chattahoochee River Basin.

Recent advances in laboratory analytical methods have given scientists the tools to detect a wide variety of contaminants at low concentrations in the environment—often 100 to 1,000 times lower than drinking-water standards (see inset, "What 'Detections' Might Mean to Human Health"). Of the 266 organic compounds characterized in this study, 50 were detected in at least one source-water sample from the Chattahoochee River. Thirty-three of these compounds were commonly detected, that is, found in at least 20 percent of the samples (table 1). The majority of the compounds detected were pesticide and pesticide degradates, but gasoline hydrocarbons, manufacturing additives, and personal-care and domestic-use products also were found. These compounds are among the most commonly detected contaminants in surface and groundwater across the Nation (Gilliom and others, 2006; Zogorski and others, 2006).

Five compounds (chloroform, atrazine, simazine, 3,4-dichloroaniline, and toluene) were present in source water throughout the year (detected in more than 90 percent of samples). Chloroform is a by-product of water treatment and may result from upstream wastewater discharges. Atrazine, simazine, and 3,4-dichloroaniline are herbicides that are commonly used on lawns, golf courses, and ornamental plantings in the Atlanta metropolitan area and in agricultural areas upstream from Atlanta. Toluene is a gasoline hydrocarbon that has many sources, including transportation and industrial uses.

Table 1. A total of 33 compounds were commonly detected (in at least 20 percent of the samples) in source water and 27 compounds in finished water.

[DEET, N,N-diethyl-*meta*-toluamide; HHCB, hexahydrohexamethylcyclopentabenzopyran; MCPA, 2-methyl-4-chlorophenoxyacetic acid]

Compound	Percent detection	
	Source water	Finished water
Disinfection by-products		
Bromodichloromethane	0	100
Bromoform	0	31
Chloroform	92	100
Dibromochloromethane	0	100
Fungicide		
Benomyl	23	0
Gasoline hydrocarbons		
Benzene	25	0
m- and *p*-Xylene	8	62
Methyl *tert*-butyl ether	25	0
Toluene	100	100
Herbicide and hebicide degradates		
2,4-D	62	100
3,4-Dichloroaniline	92	0
Atrazine	100	100
Deethylatrazine	46	69
Deisopropylatrazine	46	77
Diuron	46	46
Hydroxy atrazine	23	0
MCPA	46	62
Metolachlor	46	23
Pendimethalin	31	23
Prometon	69	31
Simazine	100	100
Insecticides		
Diazinon	23	0
Carbaryl	31	31
Fipronil	77	0
Fipronil sulfide	31	0
Fipronil sulfone	23	0
Desulfinylfipronil	54	23
Manufacturing additives		
Tris(2-butoxyethyl) phosphate	23	8
Tris(dichloroisopropyl)phosphate	46	31
Organic Synthesis Compound		
Anthraquinone	23	0
Personal-care and domestic-use products		
Caffeine	85	85
DEET	85	77
HHCB	85	69
4-Nonylphenol diethoxylate	23	38
para-Nonylphenol	15	27
Phenol	77	8
Plant- or animal-derived biochemicals		
Cholesterol	38	8
Solvents		
Acetone	0	31
Methyl ethyl ketone	0	23
Methylene chloride	0	46
p-Cresol	23	0

What "Detections" Might Mean to Human Health

The analytical methods used in this study have low detection levels—often 100 to 1,000 times lower than Federal and State standards and guidelines for protecting water quality. Detections, therefore, do not necessarily indicate a concern to human health. Rather, they help to identify the environmental presence of a wide variety of chemicals not commonly monitored in water resources, and they help to track changes in their occurrence and concentrations over time. These findings complement ongoing drinking-water monitoring required by Federal, State, and local programs, which focus primarily on post-treatment compliance monitoring of contaminants regulated by the U.S. Environmental Protection Agency in drinking water. Many of the compounds analyzed by the USGS are not included in other source-water and finished-water monitoring programs, such as the Unregulated Contaminant Monitoring Program (U.S. Environmental Protection Agency, 2007b) and the U.S. Department of Agriculture Pesticide Data Program (U.S. Department of Agriculture, 2008).

Comparisons Between Source Water and Finished Water

About 70 percent of the 33 compounds commonly detected in source water were detected in finished water and generally at similar concentrations.

Comparisons between source water and finished water are not intended to characterize treatment efficacy, but to provide a preliminary indication of the potential importance of compounds detected in source water to the quality of finished water before distribution (see inset, "Finished-Water Sampling, Water Treatment, and Significance of Comparisons to Source Water"). Eighteen of the most commonly detected organic compounds in source water also were commonly detected in finished water and often at similar low-level concentrations. These compounds included pesticides and degradates (2,4-D, deethylatrazine, deisopropylatrazine, diuron, MCPA, metolachlor, pendimethalin, prometon, simazine, carbaryl, desulfinylfipronil), personal care and domestic-use products (4-nonylphenol diethoxylate, caffeine, DEET, HHCB), and three additional compounds (chloroform, toluene, tris(dichloroisopropyl)phosphate; table 1). The herbicides 2,4-D, atrazine, and simazine were detected in 100 percent of the finished water samples, although at low concentrations. These pesticides are widely used in the Chattahoochee River watershed and across the Nation and have been frequently detected in surface water in the Atlanta metropolitan area (Frick and Dalton, 2005; Hughes and Moon, 2009).

Three disinfection by-products were detected in 100 percent of finished samples (bromodichloromethane, dibromochloromethane, chloroform), and one was frequently detected (bromoform). With the exception of chloroform, none of these compounds were detected in source-water samples. These by-products form when organic carbon in source water reacts with disinfectants, such as chlorine and (or) bromine. The presence of these compounds in finished water is well documented, understood, and expected as an outcome of drinking-water disinfection (Rook, 1974; Krasner and others, 2006). The presence of chloroform in source water could result from upstream wastewater discharges. Several compounds, including acetone, methyl ethyl ketone, *m*- and *p*-xylene, and *para*-nonylphenol, were detected in low concentrations in finished water but were not detected in source water. The presence of these compounds in finished water is not fully understood.

Finished-Water Sampling, Water Treatment, and Significance of Comparisons to Source Water

The City of Atlanta uses conventional water-treatment processes at the Chattahoochee Water Treatment Plant, including pre-screening; disinfection with sodium hypochlorite and chlorine; flocculation using alum; disinfection with sodium hypochlorite and chlorine; sedimentation; filtration through anthracite coal, sand, and coarse gravel using dual media filters; post-chemical addition (fluoride, phosphate, lime, and more chlorine); clear well storage; and distribution. Finished-water samples were collected approximately 5 hours after source-water samples were collected to account for treatment-plant retention time of the water (Frick and Dalton, 2005). Some differences between source- and finished-water quality may be attributable to sample timing and variations in retention time, as well as potential analytic variability associated with low concentrations at or near laboratory reporting levels (Kingsbury and others, 2008). It is also possible that some compounds detected in source water were transformed during the treatment process into compounds that were not monitored as part of this study. The study sampling design and resulting comparisons are not intended to characterize treatment efficacy, but to provide a preliminary indication of the potential importance of compounds detected in source water to the quality of finished water before distribution. In general, conventional treatment is not specifically designed to remove most of the organic compounds monitored in this study.

A Closer Look at Herbicides and Herbicide Degradates

The herbicides atrazine and simazine were detected in all of the source- and finished-water samples at concentrations below drinking-water standards. The similar concentrations measured in both source and finished water suggest that current treatment processes are ineffective at removing these compounds at the low concentrations measured.

The herbicides atrazine and simazine were detected in 100 percent of the source- and finished-water samples collected, with maximum concentration about 10 times lower than U.S. Environmental Protection Agency (USEPA) maximum contaminant levels (MCL) for drinking water (table 2). The concentrations of most of the herbicides detected were similar for both source and finished water, indicating that the treatment system may not be effectively removing these compounds. Both atrazine and simazine were detected year round, although concentrations greatly increased during the winter months likely because of pre-emergent applications prior to the spring growing season. A similar seasonal increase in these herbicides was observed in several smaller watersheds in the Atlanta metropolitan area, although concentrations in these smaller streams were higher, at times exceeding the USEPA MCL (Hughes and Moon, 2009).

The data collected for this study do not indicate an immediate health threat based on existing drinking-water standards. However, from 4 to 12 pesticides and pesticide degradates were detected in each finished-water sample, and the health effects of pesticide mixtures is not well understood. In addition, the atrazine degradates deisopropylatrazine and deethylatrazine were detected in about 70 percent of the finished-water samples. The transformation of parent pesticides to degradates generally results in less toxic compounds, but some degradates may have toxicities that are similar to, or greater than, those of the parent pesticide (Gilliom and others, 2006). None of the degradate compounds measured are currently regulated under the Safe Drinking Water Act.

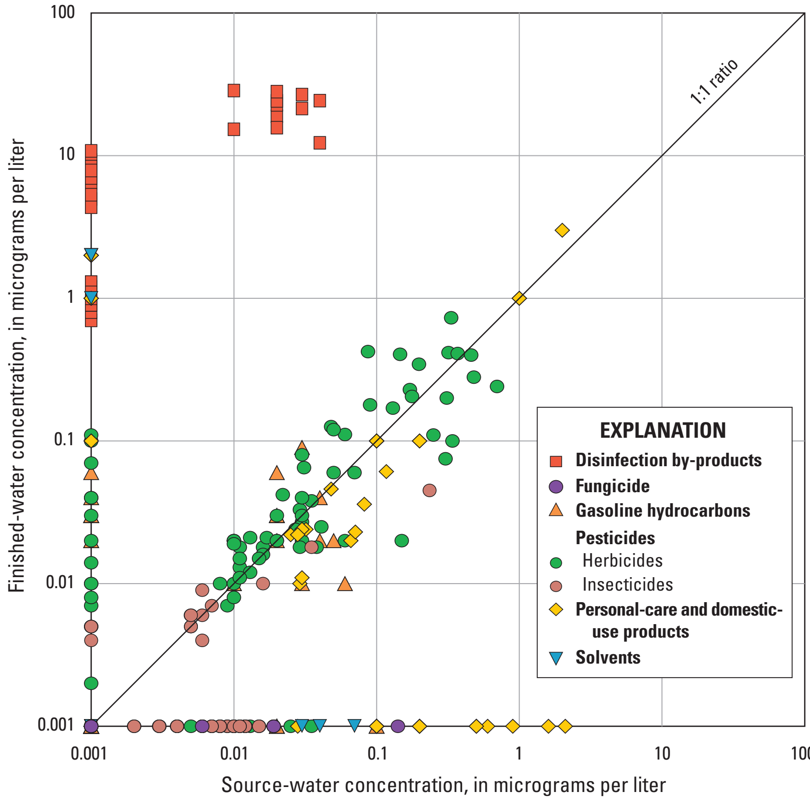

Figure 2. Many of the most commonly detected compounds had similar concentrations in source and finished water (plot along the 1:1 line). All of the disinfection by-products had higher concentrations in finished water than source water (plot above the 1:1 line); those that plot along the y-axis were not detected in source water. Similarly, many of the insecticides and some of the personal care and domestic-use products plot along the x-axis, indicating that they were not detected in finished water. With the exception of disinfection by-products, nearly all compounds have concentrations less than 1 microgram per liter.

Human-Health Benchmarks Used in This Assessment

A screening-level assessment of the potential significance of detected compounds to human health was based on a comparison of measured concentrations to available human-health benchmarks. Specifically, concentrations of regulated compounds were compared to USEPA maximum contaminant levels, and concentrations of unregulated compounds that have USEPA-published toxicity information were compared to USGS health-based screening levels, which were developed in collaboration with USEPA, New Jersey Department of Environmental Protection, and Oregon Health & Science University (Toccalino and others, 2008). About one-half of the detected compounds do not have human-health benchmarks or adequate toxicity information for evaluating results in a human-health context. Human-health benchmarks have been developed for individual compounds but not mixtures. The screening-level assessment provides an initial perspective on the potential importance of manmade organic compounds in source water; it is not a substitute for a comprehensive risk assessment, which includes many more factors, such as additional avenues of exposure.

Potential Effects on Human Health

Concentrations of all detected compounds were less than human-health benchmarks, which are available for about one-half of the detected compounds. On the basis of this screening-level assessment, adverse effects to human health are expected to be negligible (subject to limitations of available benchmarks, see inset "Human-Health Benchmarks Used in This Assessment").

Twenty-two organic compounds frequently detected in source and finished water were measured at concentrations above 0.1 microgram per liter (µg/L; table 2). Generally compounds from most of the major groups that were analyzed were detected, including disinfection by-products, pesticides, industrial compounds, and personal-care products. The prevalence of the compounds reflects their widespread use within the highly developed and populated Chattahoochee River Basin and the physical properties that allow them to persist in the environment (Gilliom and others, 2006; Zogorski and others, 2006).

Concentrations of none of the regulated compounds exceeded USEPA drinking-water standards (MCLs), and all concentrations were less than USGS Health-Based Screening Levels (HBSLs) that were developed for unregulated compounds (table 2; see inset "Human-Health Benchmarks Used in this Assessment"). Human-health benchmarks are not available for nine of the commonly occurring compounds that exceeded a concentration of 0.1 µg/L. The concentrations of four compounds were 10 times lower than their USEPA MCL or USGS HBSL human-health benchmarks—the disinfection by-products bromodichloromethane and chloroform and the herbicides atrazine and simazine (table 2). These compounds may warrant consideration for monitoring of low-concentration trends, especially because of the high concentrations of simazine that exceeded the USEPA MCL and were detected in Atlanta-area streams in a previous study (Hughes and Moon, 2009).

An important consideration in assessing the potential effects on human health is the common occurrence of mixtures of organic compounds in source- and finished-water samples. For example, the median number of compounds in source- and finished-water samples was 19 and 17, respectively. This number is comparable to findings from eight other community water systems sampled by the USGS (Kingsbury and others, 2008). The potential human-health effects of mixtures of co-occurring organic compounds are largely unknown and have not been studied extensively. The effect of one compound on another's toxicity might be additive, antagonistic, or synergistic (Hayes and others, 2006). With a few exceptions for pesticides with common modes of action, human-health benchmarks generally are not available for specific mixtures. Because MCLs and other human-health benchmarks are based on toxicity data for individual compounds, continued research is needed on the effects of specific mixtures of compounds at low concentration levels (Gilliom and others, 2006).

Table 2. Twenty-two compounds that were commonly detected in source and (or) finished water had concentrations greater than 0.1 microgram per liter. None of the concentrations exceeded a human-health benchmark; however, benchmarks are available for only 13 of the 23 compounds shown in this table.

[Reporting level shown is higher value of either source or finished water; µg/L, microgram per liter; DEET, N,N-diethyl-*meta*-toluamide; HHCB, hexahydrohexamethylcyclopentabenzopyran; MCPA, 2-methyl-4-chlorophenoxyacetic acid; E, estimated concentration; M, presence verified but not quantified; MCL, maximum contaminant level; HBSL, Health-Based Screening Level; ND, not detected; —, no human-health benchmark available]

Compound	Number of samples analyzed		Percent detection >0.1 µg/L		Reporting level, µg/L	MCL or HBSL	Maximum concentration (µg/L)	
	Source water	Finished water	Source water	Finished water			Source water	Finished water
Disinfection by-products								
Bromodichloromethane	12	13	0	100	0.028		ND	9.34
Chloroform	12	13	0	100	0.1	80[a]	E 0.04	36.7
Dibromochloromethane	12	13	0	100	0.1		ND	1.7
Fungicide								
Benomyl	13	13	7	0	0.022	40	E 0.141	ND
Gasoline hydrocarbon								
Methyl *tert*-butyl ether	12	13	25	0	0.1	—	E 0.1	ND
Herbicides								
2,4-D	13	13	54	69	0.038	70	E 0.48	0.41
Atrazine	13	13	23	23	0.007	3	0.304	0.345
Diuron	13	13	8	8	0.016	2	0.15	0.12
MCPA	13	13	31	31	0.07	30	E 0.44	E 0.39
Simazine	13	13	38	62	0.005	4	0.698	0.73
Insecticide								
Carbaryl	13	13	8	0	0.018	40	0.25	0.04
Manufacturing additives								
Tris(2-butoxyethyl) phosphate	13	13	23	8	0.5	—	E 0.4	E 0.1
Tris(dichloroisopropyl) phosphate	8	10	13	13	0.5	—	E 0.1	E 0.1
Organic synthesis compound								
Anthraquinone	12	13	17	0	0.5	—	E 0.1	ND
Personal-care and domestic-use products								
Caffeine	13	13	8	0	0.018	—	0.117	0.061
DEET	13	8	85	38	0.5	—	E 0.2	E 0.1
HHCB	13	13	54	15	0.5	—	E 0.1	E 0.1
4-Nonylphenol diethoxylate	13	13	23	38	5	—	2	3
Phenol	13	13	77	8	0.5	2,000	2.1	E 0.1
Plant- or animal-derived biochemicals								
Cholesterol	8	13	0	8	2	—	M	E 1
Solvents								
Acetone	12	13	0	31	6	6,000	ND	E 2
Methyl ethyl ketone	12	13	0	23	2	4,000	ND	4.1

[a] MCL of 80 µg/L is for total trihalomethanes (chloroform, bromodichloromethane, dibromochloromethane, and bromoform). Water utility comparison to the MCL is based on a moving average of quarterly samples collected at specific points in the distribution system (4 per treatment plant).

Source Water-Quality Assessments Conducted across the Nation as part of the NAWQA Program

Beginning in 2002, the NAWQA Program initiated a Source Water-Quality Assessment (SWQA) Program to characterize the quality of water used as a source of supply at selected community water systems across the United States (Delzer and Hamilton, 2007). The long-term goal of the SWQA Program is to complete as many as 30 assessments by 2012 at systems that withdraw water from streams using standard protocols and nationally consistent methods (U.S. Geological Survey, variously dated). This fact sheet highlights findings from the Chattahoochee River study, which is one of the first nine community water systems sampled as part of the SWQA Program. The fact sheet serves as a companion product to USGS Data Series 268 and USGS Scientific Investigations Report 2008–5208, which present findings for the nine systems across the United States (Carter and others, 2007; Kingsbury and others, 2008).

Chattahoochee River Findings in a National Context and Possible Implications

Many of the compounds detected most commonly in water from the Chattahoochee River (tables 1 and 2) are among the most commonly detected in ambient stream water and groundwater across the Nation (Gilliom and others, 2006; Zogorski and others, 2006). In addition, the occurrence and concentrations of compounds in source- and finished-water samples collected from the Chattahoochee River are similar to those detected at other community water systems, which were sampled for a USGS study of anthropogenic compounds (Kingsbury and others, 2008). Findings in a national context, however, are considered preliminary because some compounds included in this study have only recently been monitored systematically in source and finished water, including for example, plant- or animal-derived biochemicals, such as cholesterol, and those used for personal care, including caffeine, DEET, and 4-nonylphenol diethoxylate. Continued research is needed to better understand sources, transport mechanisms, trends, fate in the environment, and possible links among these compounds and human health.

The USGS will continue to collaborate with and complement the work of other Federal, State, and local organizations, and communicate findings and possible implications and future needs such as:

- Increased emphasis on watershed management and source-water protection strategies to help minimize the sources and transport of compounds to source water and ultimately to finished water.
- Continued research to better understand and communicate the relevance of organic compounds detected in untreated source water and treated finished water, the toxicity of these compounds and mixtures of these compounds, and the possible implications for human health and the environment.
- Current and future monitoring to identify compounds not typically evaluated in source water, but commonly present in finished water.

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USGS Promotes Public Access to Water-Quality Information

This fact sheet, additional data and investigations reports, and other information are available on the World Wide Web at *http://water.usgs.gov/nawqa/swqa/*. Included at this Web site are downloadable data on organic compound occurrence, information on sampling designs and methodology, background on data analyses, and frequently asked questions.

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