



VOLATILE ORGANIC COMPOUNDS IN GROUND WATER IN THE CONNECTICUT, HOUSATONIC, AND THAMES RIVER BASINS, 1993 – 1995



National Water Quality Assessment
Fact Sheet 029-97

Connecticut, Housatonic, and Thames River Basins Study Unit

Twenty-five volatile organic compounds (VOCs) were detected in water samples from 46 percent of wells in the Connecticut, Housatonic, and Thames River Basins NAWQA study area collected from July 1993 through September 1995. VOCs were detected in shallow monitoring wells (48 percent) screened in surficial aquifers and deeper, domestic- and institutional-supply wells (37 percent) completed in fractured bedrock. The gasoline additive MTBE was the most commonly detected VOC, followed by chloroform (25 and 23 percent of wells, respectively). VOC detections in ground water are related to urban land use, and the frequency of VOC detections and the total concentration of VOCs in ground water increased with increasing population density. Concentrations of five VOCs exceeded the U.S. Environmental Protection Agency's Maximum Contaminant Levels or Lifetime Health Advisories, but most (64 percent) VOC detections were at low concentrations (less than 1.0 microgram per liter) and may originate from nonpoint sources.

NATIONAL WATER-QUALITY ASSESSMENT PROGRAM

The National Water Quality Assessment (NAWQA) Program of the U.S. Geological Survey is designed to describe current water-quality conditions for a large part of the Nation's ground- and surface-water resources, to describe how water quality is changing over time, and to improve our understanding of the natural and human factors that affect water quality. These goals are being achieved through investigations of 59 of the Nation's most important river basins and aquifer systems, referred to as study units. The Connecticut, Housatonic, and Thames River Basins study was among the first 20 investigations that began this water-quality assessment in 1991.

Introduction

Many volatile organic compounds (VOCs) are manmade chemicals that are used and produced in the manufacture of paints, adhesives, petroleum products, pharmaceuticals, and refrigerants. They are often components of fuels, solvents, hydraulic fluids, paint thinners, and dry cleaning agents commonly used in urban settings. VOC contamination of drinking-water supplies is a human health concern because many are toxic and are known or suspected human carcinogens (U.S. Environmental Protection Agency, 1996).

Water samples collected from 133 wells in the Connecticut, Housatonic, and Thames River Basins in New England from July 1993 through September 1995 were analyzed for volatile organic compounds (VOCs) (fig. 1). This report presents the results of VOC analyses and describes the occurrence of VOCs in relation to

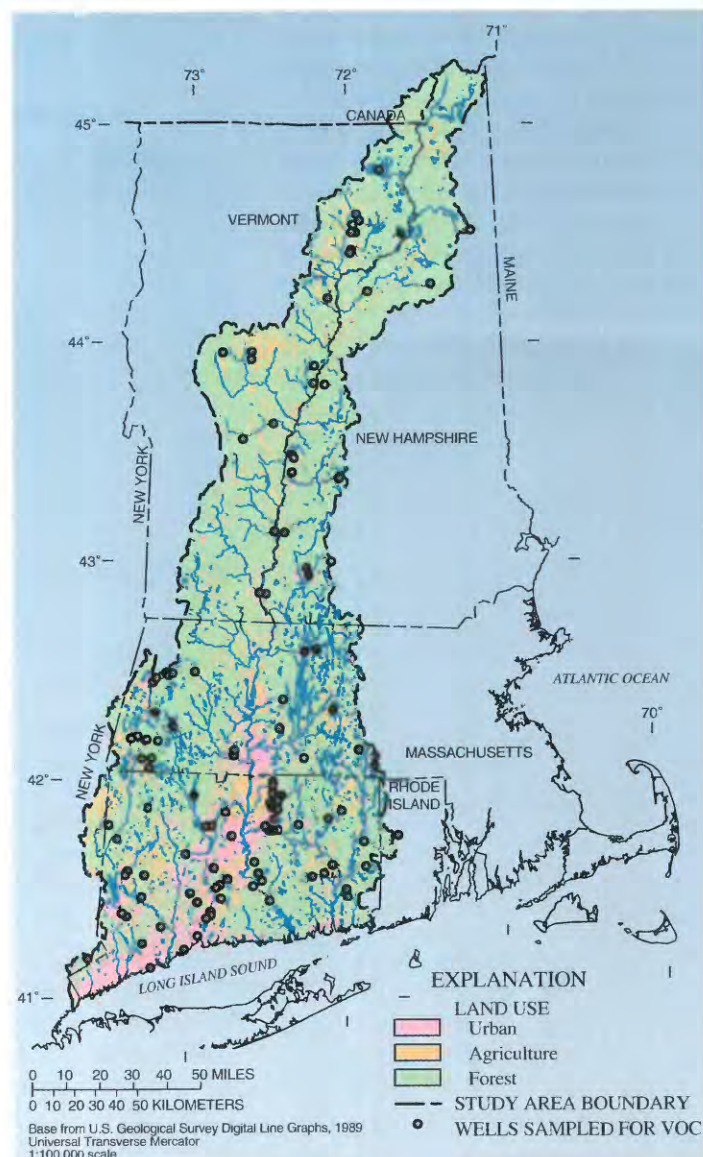


Figure 1. Distribution of wells sampled for volatile organic compounds (VOCs) in the Connecticut, Housatonic, and Thames River Basins.

aquifer type and land use. The data were collected as part of the U.S. Geological Survey's (USGS) National Water Quality Assessment Program (NAWQA).

The Connecticut, Housatonic, and Thames River Basins study encompasses an area of 15,760 square miles extending from Canada to Long Island Sound (fig. 1). In 1990, the population of the study area was about 4.5 million people, most residing in the southern part of the area. About 10 percent of the study area is classified as urban, 74 percent is forested, 12 percent is agricultural, and 4 percent is barren or other land-use categories.

Water samples were collected from wells completed in surficial and bedrock aquifers. Unconsolidated surficial aquifers include stratified-drift deposits and alluvium. Sand and gravel, which was transported by glacial meltwaters, sorted, and deposited in layers of similar grain size (stratified drift) in valleys and lowland areas, is the most productive source of ground water in the study area. Thin layers of alluvium that overlie these stratified-drift deposits in some river valleys are hydraulically connected and undifferentiated from the glacial aquifers. Fractured bedrock underlies the entire study unit and is an important source of water for self-supplied domestic, commercial, and institutional users.

A network of 103 monitoring wells screened in the surficial aquifers were sampled from July 1993 through September 1995 for VOCs. The monitoring-well network included 86 shallow wells (less than 50 feet deep) randomly distributed in stratified-drift aquifers underlying areas of undeveloped (forested), agricultural, and urban land use. Another 13 monitoring wells were installed to depths of 24 to 100 feet along a transect through the urban center of Manchester, Connecticut, to examine changes in water quality with distance, depth, and time along a ground-water-flow path through the surficial aquifer. Four very shallow (5 feet) monitoring wells were completed in streambed alluvium in areas where ground water discharges to urban streams in Hamden and Manchester, Connecticut. All 103 monitoring wells in surficial aquifers were sampled using a small-diameter, stainless steel and Teflon submersible pump.

In addition to the monitoring-well network, 30 existing domestic or

institutional water-supply wells completed in fractured crystalline bedrock aquifers also were sampled for VOCs during the summer of 1995. The water-supply wells were randomly selected and distributed across more than 12,000 square miles of the study area. Land use surrounding the water-supply wells ranged from forested to urban. The wells ranged from 41 to 605 feet deep, but typical of bedrock wells in New England, they are cased for only a few tens of feet through the overburden (surficial unconsolidated material) and any weathered shallow bedrock. All water-supply wells sampled have electric submersible pumps with intakes set near the bottom of the well. Samples were collected from existing plumbing outlets before the water entered any pressurized holding tanks, water filters, or water-conditioning systems.

Well selection, construction methods, and sampling protocols used are described by Koterba and others (1995) and Lapham and others (1995). VOC samples were analyzed using purge and trap capillary gas chromatography/mass spectrometry (Raese and others, 1995; Rose and Schroder, 1995). The minimum concentration reported by the laboratory is 0.2 microgram per liter for all VOCs except dibromochloropropane, toluene, and xylene (1.0 microgram per liter). In total, 250 water samples were analyzed for VOCs, including 45 quality-assurance samples (mostly field blanks) to evaluate and ensure data reliability.

Volatile Organic Compounds

Twenty-five VOCs were detected in water samples from 46 percent of the wells sampled in the Connecticut, Housatonic, and Thames River Basin study area (table 1). Laboratory analyses indicated concentrations ranged from 0.2 to 300 micrograms per liter. The gasoline oxygenate methyl *tert*-butyl ether (MTBE), the only ether and the most frequently detected VOC, was present in 25 percent of all wells sampled. Halogenated alkanes—chlorinated or fluorinated saturated aliphatic hydrocarbons including chloroform, 1,1-dichloroethane, dichlorodifluoromethane, and five additional compounds—were collectively the most frequently detected VOCs (fig. 2). Chloroform, which can form as a

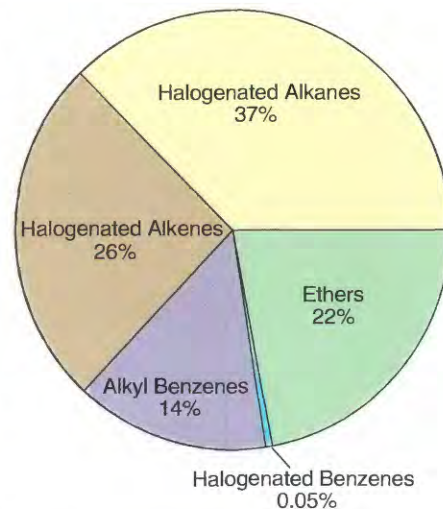


Figure 2. Percentage of volatile organic compound detections by compound class in ground-water samples from the Connecticut, Housatonic, and Thames River Basins, 1993-95.

consequence of disinfection of drinking-water supplies, was the second most frequently detected compound, and was present in 23 percent of the wells sampled. Halogenated alkenes, including the solvents *cis*-1,2 dichloroethene, tetrachlorethane, trichloroethene, were the second most frequently detected category of VOCs. Naphthalene was the most frequently detected compound of 12 alkyl benzenes analyzed for (fig. 3), but nine of these compounds were detected exclusively in one well that contained a high concentration of hydrocarbons. Only one halogenated benzene (bromobenzene) was detected.

The overall frequency of VOC detections is not significantly different for the surficial and bedrock aquifers, as 48 percent of the monitoring wells and 37 percent of the water-supply wells contained VOCs, but the types of compounds detected in the two aquifers differed. Twenty-five compounds were present in water samples from the surficial aquifers, but only four of these compounds (MTBE, chloroform, toluene, and dichlorodifluoromethane) were detected in water samples from wells completed in bedrock. Only one compound was detected in 64 percent of the water samples from water-supply wells; however, more than one compound was detected in 74 percent of water samples from monitoring wells.

The U.S. Environmental Protection Agency (1996) has issued, drafted, or

Table 1. Volatile organic compounds detected in ground-water samples by well, aquifer type, and land use in the Connecticut, Housatonic, and Thames River Basins, 1993-95.

[The minimum reporting level for all volatile organic compounds is 0.2 µg/L (micrograms per liter) except for toluene and xylenes, which are 1.0 µg/L; N, number of wells sampled; ND, number of wells with detections; MC, maximum concentration detected (or reporting level when no detections reported); <, less than, >, greater than. All detections are shaded for the convenience of the reader. Compounds with detections exceeding Maximum Contaminant Levels or Lifetime Health Advisories (U.S. Environmental Protection Agency, 1996) are shown in red.]

VOLATILE ORGANIC COMPOUNDS	MONITORING WELLS IN SURFICIAL AQUIFERS										WATER-SUPPLY WELLS IN BEDROCK AQUIFER	
	Land-use study wells						Urban flowpath wells		Urban streambed wells			
	Undeveloped N = 22		Agricultural N = 24		Urban N = 40		N = 13		N = 4		N = 30	
	ND	MC (µg/L)	ND	MC (µg/L)	ND	MC (µg/L)	ND	MC (µg/L)	ND	MC (µg/L)	ND	MC (µg/L)
Halogenated alkanes												
Bromodichloromethane	1	.2	0	<.2	0	<.2	1	.8	0	<.2	0	<.2
Carbon tetrachloride	0	<.2	0	<.2	1	.9	0	<.2	0	<.2	0	<.2
Chloroform	1	2.6	2	.4	13	3.1	9	13	2	.4	4	.9
1,2-Dibromoethane	0	<.2	1	1.4	0	<.2	0	<.2	0	<.2	0	<.2
1,1-Dichloroethane	0	<.2	0	<.2	4	2.2	1	.3	0	<.2	0	<.2
Dichlorodifluoromethane	0	<.2	0	<.2	1	.8	1	.7	0	<.2	2	1.2
Methylene chloride	0	<.2	1	2.8	2	.9	1	.8	0	<.2	0	<.2
1,1,1-Trichloroethane	0	<.2	0	<.2	3	1.1	0	<.2	0	<.2	0	<.2
Halogenated alkenes												
cis-1,2-Dichloroethene	0	<.2	0	<.2	4	.9	3	2.7	2	4.5	0	<.2
Tetrachloroethene	0	<.2	0	<.2	10	250	2	.4	1	50	0	<.2
Trichloroethene	0	<.2	0	<.2	6	63	4	11	1	6.0	0	<.2
Ether												
Methyl tert-butyl ether	0	<.2	2	.4	16	2.4	6	.8	2	5.8	7	2.2
Alkyl benzene												
Benzene	0	<0.2	1	0.6	1	73	0	<0.2	0	<0.2	0	<0.2
n-Butylbenzene	0	<.2	0	<.2	1	6.8	0	<.2	0	<.2	0	<.2
sec-Butylbenzene	0	<.2	0	<.2	1	4.4	0	<.2	0	<.2	0	<.2
Ethylbenzene	0	<.2	0	<.2	1	270	0	<.2	0	<.2	0	<.2
Isopropylbenzene	0	<.2	0	<.2	1	27	0	<.2	0	<.2	0	<.2
p-Isopropyltoluene	0	<.2	0	<.2	2	6.3	0	<.2	0	<.2	0	<.2
Naphthalene	1	.3	4	.3	5	70	0	<.2	0	<.2	0	<.2
n-Propylbenzene	0	<.2	0	<.2	1	47	0	<.2	0	<.2	0	<.2
Toluene	0	<1	2	2.2	1	23	0	<1	0	<1	3	1.8
1,2,4-Trimethylbenzene	0	<.2	3	.2	1	260	0	<.2	0	<.2	0	<.2
1,3,5-Trimethylbenzene	0	<.2	0	<.2	1	18	0	<.2	0	<.2	0	<.2
Xylenes (total)	0	<1	0	<1	1	300	0	<1	0	<1	0	<1
Halogenated benzene												
Bromobenzene	0	<.2	1	.4	0	<.2	0	<.2	0	<.2	0	<.2

proposed drinking-water regulations and (or) health advisories for 23 of the 25 VOCs detected in ground water in this study. Minimum laboratory reporting limits are

less than one-half of the Maximum Contaminant Levels (MCLs) or Lifetime Health Advisories (HAs) for all VOCs except 1,2-dibromomethane (EDB) and

dibromochloropropane (DBCP); reporting limits for these compounds are 4 and 5 times, respectively, greater than the standards. Five of the 25 VOCs detected in

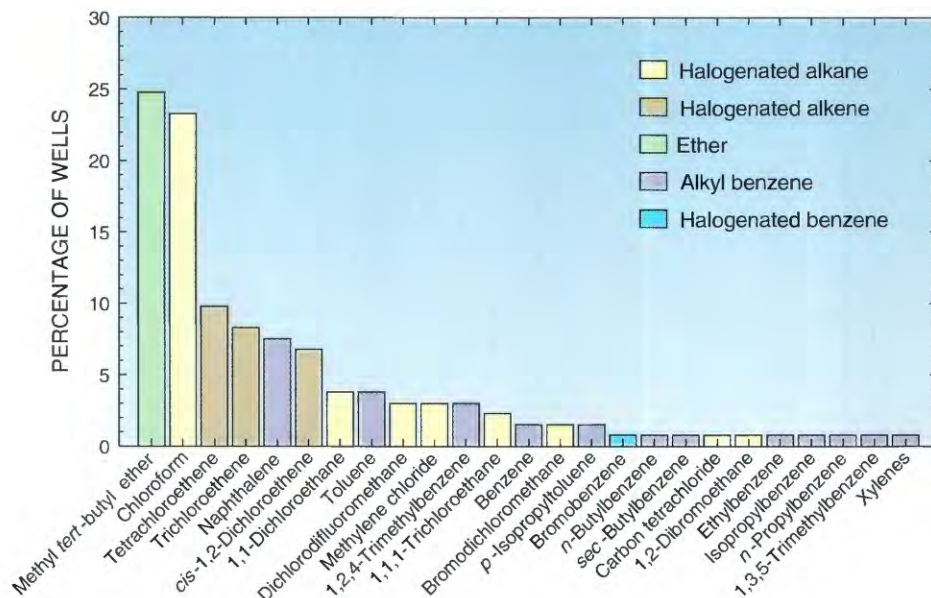


Figure 3. Frequency of detection of 25 volatile organic compounds in ground-water samples from the Connecticut, Housatonic, and Thames River Basins, 1993-95.

monitoring wells, including benzene, 1,2-dibromoethane, naphthalene, tetrachloroethene, and trichloroethene, were measured at concentrations exceeding MCLs or HAs. Eight of the 25 compounds detected in monitoring wells also have been identified as either known, probable, or possible human carcinogens (U.S. Environmental Protection Agency, 1996). Although monitoring wells installed for this study are not used for drinking water, public-supply wells commonly tap the same surficial aquifers, but are generally screened deeper than the monitoring wells. Of the four VOCs detected in samples from water-supply wells, none were present at concentrations exceeding MCLs or HAs, but two of the compounds, chloroform and MTBE, have been linked to cancer and other adverse health effects.

The presence of VOCs in ground water does not appear to be directly related to the depth of wells (fig. 4). VOCs were detected in monitoring wells ranging from 5 to 90 feet deep, yet were not detected in other monitoring wells 5 to 100 feet deep. Although the water-supply wells collectively are much deeper than the monitoring wells, the depth of water-supply wells in which VOCs were detected and those in which VOCs were not detected were not significantly different. VOCs were detected in supply wells ranging from 123 to 605 feet deep, but were not detected in similar wells 41 to 500 feet deep. The presence of VOCs

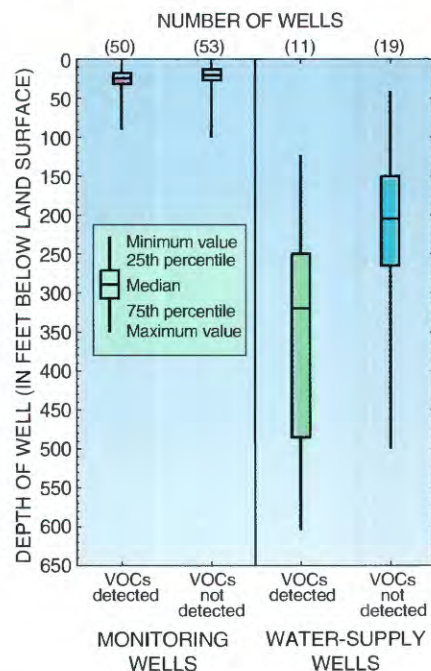


Figure 4. Comparison of depths of wells with and without detections of volatile organic compounds (VOCs) in the Connecticut, Housatonic, and Thames River Basins.

in deep bedrock wells does not necessarily indicate that VOCs are carried by deep ground-water circulation, but rather that they may enter these wells through leaky well seals or shallow fractures.

The occurrence of VOCs in ground water can be related to the overlying land use (fig. 5). Only two (9 percent) of the monitoring wells in undeveloped areas

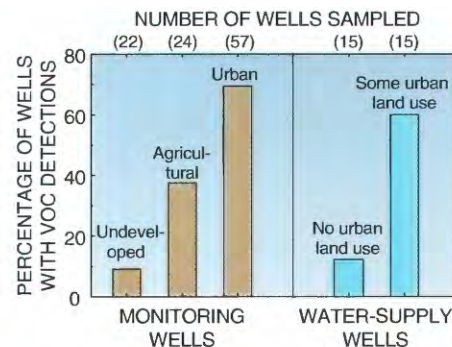


Figure 5. Percentage of monitoring and water-supply wells with volatile organic compound (VOC) detections in the Connecticut, Housatonic, and Thames River Basins, 1993-95.

contained VOCs and only three compounds were detected. Nine compounds were measured in samples from 37 percent of monitoring wells in agricultural areas, due in part to the use of some VOCs (1,2 dibromoethane, naphthalene) as pesticides. But the occurrence of VOCs is most directly related to urban land use, as 70 percent of monitoring wells in urban areas contained one or more compound. Twenty-two compounds were detected in the urban wells (table 1) and 19 of these occurred only or most often in urban wells. VOC detections in water-supply wells also may be related to urban land use. VOCs were detected in 9 of 15 water-supply wells with some urban land present within one-quarter mile of the well, but in only 2 of 15 wells with no urban land near the well (fig. 5). The distribution of 133 wells sampled for VOCs and the 61 wells with VOC detections is shown in figure 6. Although 76 percent of the wells sampled for VOCs were in the southern part of the study area (Conn., Mass., N.Y., and R.I.), 90 percent of the VOC detections were in this area.

The relation between the occurrence of VOCs in ground water and urban land use also reflects population density. Although VOCs have been detected in wells in areas of very low population density (less than 20 persons per square mile), the frequency of detection increases sharply with increasing population density (fig. 7). In high-density, urban areas (greater than 2,000 persons per square mile), VOCs were detected in three out of four wells (76 percent). The total concentration of VOCs detected in any well (the sum of all detected VOC concentrations) also increased significantly for wells in areas with more than 100 persons per square mile (fig. 8).

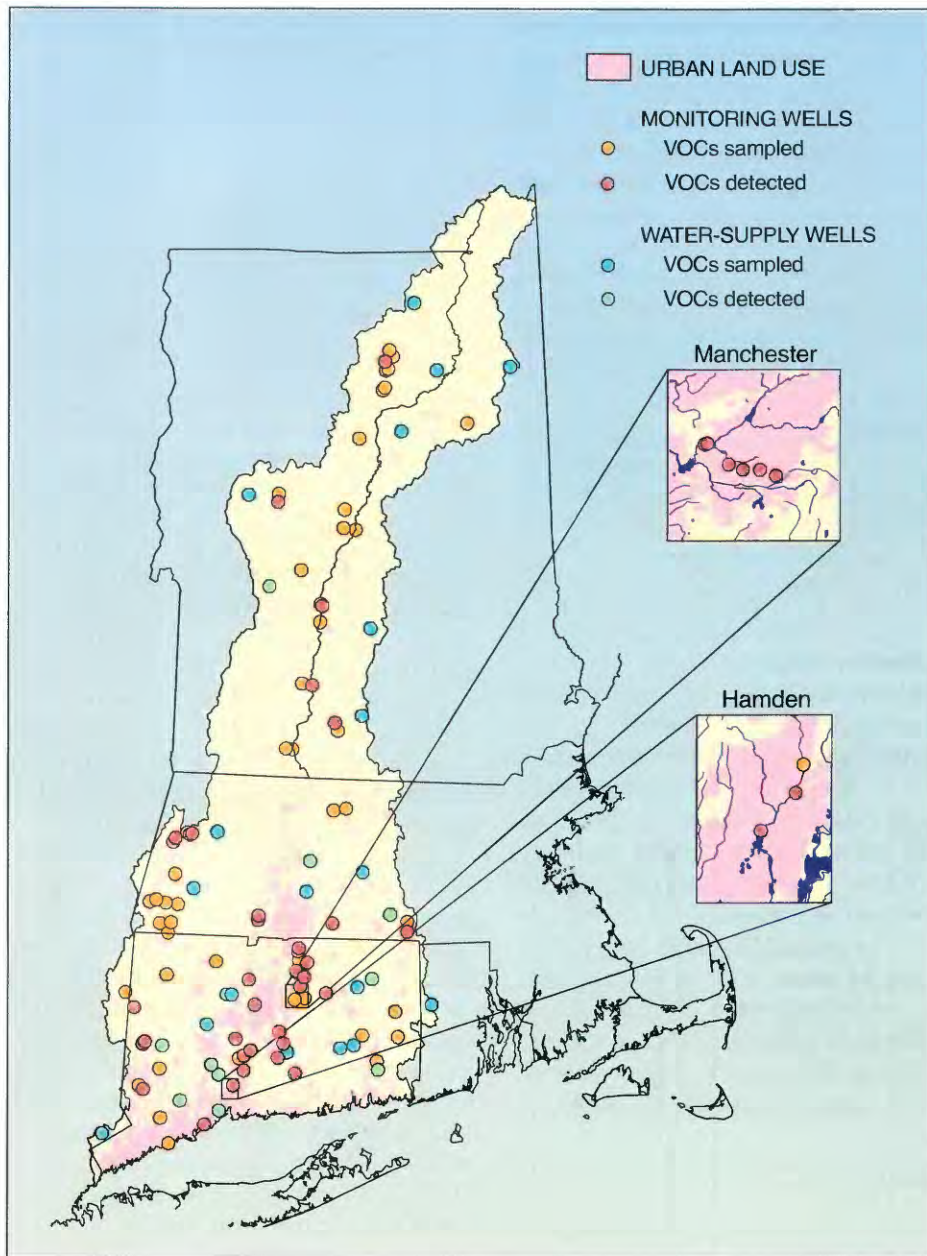


Figure 6. Areal distribution of wells in which volatile organic compounds (VOCs) were sampled and detected in the Connecticut, Housatonic, and Thames River Basins, 1993-95.

Point and nonpoint sources may contribute VOCs to ground water in the study area. High concentrations of VOCs such as tetrachlorethane (250 µg/L), trichloroethene (63 µg/L), benzene (73 µg/L), and total xylenes (300 µg/L) in some urban monitoring wells, suggest the possibility of nearby point sources. However, the bulk of the VOC detections (64 percent) were at concentrations less than 1.0 µg/L, which may be more indicative of nonpoint sources. Many of the VOCs detected in this study are released to the atmosphere by industry,

vehicle exhaust, or other urban and agricultural sources, and VOCs have been detected in outdoor air (Shah and Singh, 1988). Possible sources for the presence of VOCs at low concentrations in ground water also include infiltration of urban runoff, exfiltration from sanitary sewers, effluent from domestic and commercial septic tanks, and small leaks or spills of solvents, paints, refrigerants, motor oils and fuels, and other organic chemicals.

Evidence as to the source of some VOCs is conflicting. For example, use of the gasoline additive MTBE in some

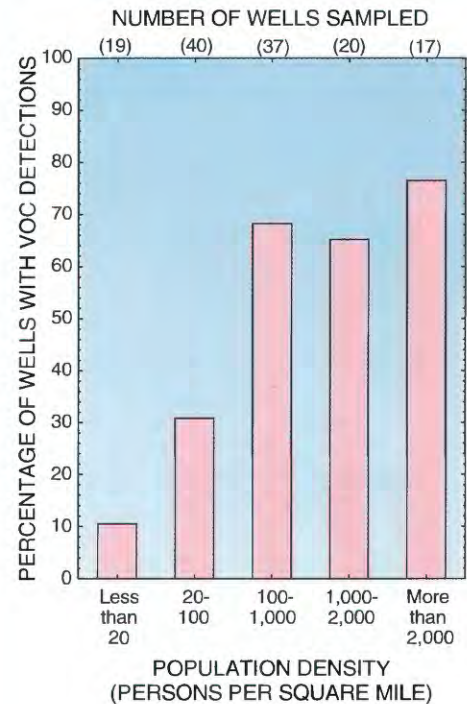


Figure 7. Percentage of wells with detections of volatile organic compounds (VOCs) in ground-water samples relative to population density in the Connecticut, Housatonic, and Thames River Basins, 1993-95.

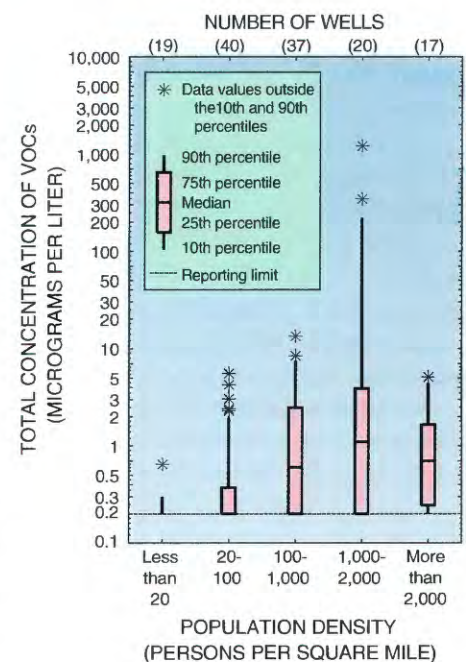


Figure 8. Total concentrations of volatile organic compounds (VOCs) in ground-water samples relative to population density in the Connecticut, Housatonic, and Thames River Basins, 1993-95.

metropolitan areas was recently required by the 1990 Clean Air Act Amendments to reduce atmospheric concentrations of

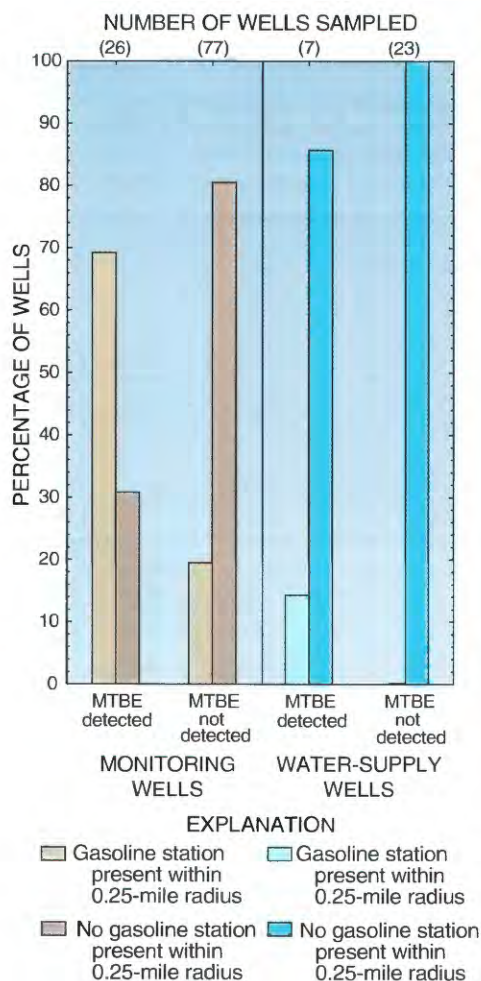


Figure 9. Percentage of monitoring and water-supply wells with and without detections of methyl tert-butyl ether (MTBE) relative to nearby gasoline stations in the Connecticut, Housatonic, and Thames River Basins, 1993-95.

carbon monoxide and ozone from automobile emissions. Yet MTBE was the most frequently detected VOC in this study and was detected in shallow urban wells in seven other areas of the Nation (Squillace and others, 1996). Sixty-nine percent of MTBE detections have been in shallow monitoring wells that are within one-quarter mile of gasoline stations or other known underground gasoline storage tanks (fig. 9) that could act as point sources for MTBE and other hydrocarbon contaminants (Garrett and others, 1986). However, a substantial number (31 percent) of MTBE detections were in shallow wells that are not near gasoline stations, as were most (86 percent) of MTBE detections in the deeper water-supply wells. Few (12 percent) of the MTBE detections occur concurrently with benzene, toluene, ethylbenzene, or xylenes (BTEX) compounds, which are commonly used indicators of gasoline contamination. These facts and low concentrations (from 0.2 to 5.8



Recent widespread use of MTBE in reformulated or oxygenated gasoline has led to its frequent detection in ground water beneath urban areas.

micrograms per liter) of MTBE measured in 33 wells in the study area suggest that most MTBE detections in this study cannot be attributed to nearby gasoline leaks and spills. Transport of nonpoint source, atmospheric MTBE through the unsaturated zone to a shallow water table has recently been simulated to produce dissolved MTBE concentrations in the range observed in ambient ground water in New England (Pankow and others, 1996).

References Cited

- Garrett, Peter, Moreau, Marcel, and Lowry, J.D., 1986, MTBE as a ground water contaminant, *in* Proceedings of Petroleum Hydrocarbons and Organic Chemicals in Ground Water -- Prevention, Detection, and Restoration, Nov. 12-14, 1986: Houston, Texas, National Water Well Association and American Petroleum Institute, p. 227-238.
- Koterba, M.T., Wilde, F.D., and Lapham, W.W., 1995, Ground-water data-collection protocols for the National Water-Quality Assessment Program--Collection and documentation of water-quality samples and related data: U.S. Geological Survey Open-File Report 95-399, 113 p.
- Lapham, W.W., Wilde, F.D., and Koterba, M.T., 1995, Ground-water data-collection protocols for the National Water-Quality Assessment Program--Selection, installation, and documentation of wells, and collection of related data: U.S. Geological Survey Open-File Report 95-398, 69 p.
- Pankow, J.F., Thomson, N.R., and Johnson, R.L., 1996, Modeling the atmospheric inputs of MTBE to groundwater systems [abs.], in Society of Environmental Toxicology and Chemistry, 17th annual meeting, Washington, D.C., Nov. 17-21, 1996, Abstract Book: Pensacola, Fla., Society of Environmental Toxicology and Chemistry, p. 115.
- Raese, J.W., Rose, D.L., and Sandstrom, M.W., 1995, U.S. Geological Survey laboratory method for methyl tert-butyl ether and other fuel oxygenates: U.S. Geological Survey Fact Sheet 219-95, 4 p.
- Rose, D.L., and Schroeder, M.P., 1995, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory--Determination of volatile organic compounds in water by purge and trap capillary gas chromatography/mass spectrometry: U.S. Geological Survey Open-File Report 94-708, 26 p.
- Shah, J.J., and Singh, H.B., 1988, Distribution of volatile organic chemicals in outdoor and indoor air: Environmental Science and Technology, v. 22, no. 12, p. 1381-1388.
- Squillace, P.J., Zogorski, J.S., Wilber, W.G., and Price, C.V., 1996, Preliminary assessment of the occurrence and possible sources of MTBE in groundwater in the United States, 1993-1994: Environmental Science and Technology, v. 30, no. 5, p. 1721-1730.
- U.S. Environmental Protection Agency, 1996, Drinking water regulations and health advisories: Office of Water, Washington, D.C., EPA 822-R-96-001, 16 p.

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