Occurrence and Concentrations of Volatile Organic Compounds in Shallow Ground Water in the Lower Susquehanna River Basin, Pennsylvania and Maryland

Matthew H. Daly and Bruce D. Lindsey

U.S. Department of the Interior
U.S. Geological Survey
Water-Resources Investigations Report 96-4141

ABSTRACT

This report presents the results of a regional assessment of volatile organic compounds (VOC's) in ground water from six sampling areas within the Lower Susquehanna River Basin. The sampling areas, selected to represent aquifers where ground water is used as a drinking water supply, include four areas underlain by limestone, one area underlain by crystalline bedrock, and one area underlain by interbedded sandstone and shale. The land use is rural in five areas and urban in one area. Samples were collected in 1993-95 from 118 wells ranging from 30 to 226 feet deep.

Analyses for 60 VOC's at detection levels ranging from 0.05 to 0.2 µg/L (micrograms per liter) reveal the presence of 24 compounds. The compounds were present in water from 32 of the 118 wells. Methyl *tert*-butyl ether was the most commonly detected compound. Concentrations of methyl *tert*-butyl ether, found in 16 of the 118 wells, ranged from 0.11 to 51 µg/L. Chloroform was the second most commonly detected compound. The highest concentration detected in a water sample was 61 µg/L of chloroform. None of the detections in samples from wells used as drinking water supplies exceeded the Maximum Contaminant Levels or Lifetime Health Advisory Levels established by the U. S. Environmental Protection Agency. However, the 51 µg/L of methyl *tert*-butyl ether, detected in water from a monitoring well, is in the 20 to 200 µg/L range proposed for a Lifetime Health Advisory Level.

The occurrence of VOC's in limestone aquifers in the Great Valley near Harrisburg, Pa., is influenced by land use. VOC's occur more frequently in the urban area than in the agricultural area. Within the urban area, analyses of samples from wells, springs, and a spring-fed stream show contaminated ground water discharging from springs and flowing into the stream.

INTRODUCTION

The presence of volatile organic compounds (VOC's) in ground water is a potential human health concern for those using ground water as a drinking water supply. VOC's are a group of organic compounds in products such as gasolines, paints, paint thinners, and solvents used for dry cleaning and metal degreasing. The compounds are typically used in liquid form and are defined as volatile because many can readily evaporate. Gasoline and other substances containing VOC's can find their way into the ground water through point sources such as leaking storage tanks or direct spills. Compounds also can enter the ground water from nonpoint sources. Stormwater runoff in developed areas can contain VOC's from roads and parking lots. Some airborne compounds can mix with rain, and rainfall containing VOC's also may recharge aquifers as a nonpoint source of contamination. Once in the ground water, VOC's can degrade the quality of water supplies.

The U.S. Geological Survey's (USGS) National Water-Quality Assessment (NAWQA) program was implemented to assess the quality and characterize the trends in quality of the nation's ground water and surface water. The program is designed to allow scientists to gain a better understanding of the roles of natural and human factors that affect the quality of water resources (Gilliom and others, 1995). One goal of the program is to determine the occurrence and distribution of VOC's in shallow ground water. Shallow ground water is found in the uppermost part of an unconfined aquifer and represents the most recently recharged water that might be affected by land-use activities. In Pennsylvania and Maryland, water from unconfined aquifers is an important source of drinking water. Therefore, as part of the NAWQA program, an assessment was made of the occurrence and distribution of VOC's in shallow ground water from selected aquifers in the Lower Susquehanna River Basin study unit in Pennsylvania and Maryland.

Purpose and Scope

This report presents the results of a regional assessment of the occurrence and concentrations of VOC's in ground water from six areas in the Lower Susquehanna River Basin study unit. The selected areas were sampled to determine the spatial distribution of VOC's in six aquifers used as drinking water supplies. The lithologies of the unconfined fractured-bedrock aquifers include four areas underlain by limestone, one area underlain by crystalline bedrock, and an area underlain by sandstone and shale. Wells in rural and urban areas underlain by limestone in the Great Valley were sampled to determine the effects of land use on the occurrence of VOC's in ground water. Also, surface water from Cedar Run and ground water from springs feeding Cedar Run were sampled to determine the occurrence and concentrations of VOC's in an urban stream. Between 1993 and 1995, 118 wells throughout 6 areas in the Lower Susquehanna River Basin study unit were sampled for VOC's in shallow ground water.

Description of Study Area

The Lower Susquehanna River Basin study unit drains 9,200 mi^2 (square miles), extending from Sunbury, Pa., downstream to the Chesapeake Bay, Md., and also includes 150 mi^2 of streams in Chester and Cecil Counties where streams drain directly to the Chesapeake Bay (fig. 1). Approximately 47 percent of the study unit is forested, and agricultural land use makes up about 47 percent of the area (Risser and Siwiec, in press). Estimated populations of major metropolitan areas in the study unit are 588,000 in the Harrisburg-Lebanon-Carlisle area, 423,000 in the Lancaster area, 418,000 in York, and 131,000 in Altoona (U.S. Bureau of the Census, 1992).

Ground water is widely used as a drinking water supply in the study unit. According to the 1990 census, approximately 38 percent of the 800,000 households in the study unit rely on domestic wells for their drinking water. Municipal water supplies serve approximately 59 percent of the residents in the basin, and about 20 percent of the municipal systems use ground water for their supply.

Ground water from six areas in the study unit was sampled for this study. Each area is called a subunit and is defined by the physiographic location in the study unit, the aquifer lithology, and the overlying land use. The physiographic areas studied included the Appalachian Mountain and Great Valley Sections of the Ridge and Valley Physiographic Province and the Upland and Lowland Sections of the Piedmont Physiographic Province. The subunits were selected to obtain information about aquifers that currently are used as important drinking water supplies. Lithologies of the fractured-bedrock aquifers include one area underlain by crystalline bedrock, an area underlain by sandstone and shale, and four areas underlain by limestone and dolomite. The areas underlain by limestone and dolomite are referred to as limestone subunits in this report.

The aquifers underlying each subunit have an overlying land use that can affect the quality of recently recharged ground water. Five subunits are rural, and one is urban (table 1, fig. 1). The definition of rural includes areas of agricultural and forested land uses (Anderson and others, 1976). The five rural subunits are the Appalachian Mountain sandstone and shale (light blue), Appalachian Mountain limestone agricultural (blue), Great Valley limestone agricultural (light green), Piedmont crystalline (light red), and the Piedmont limestone agricultural (red). The urban subunit is the Great Valley limestone urban (green). This subunit is centered around the greater Harrisburg area and includes the urbanizing corridor from western Cumberland County to Lebanon, Pa.

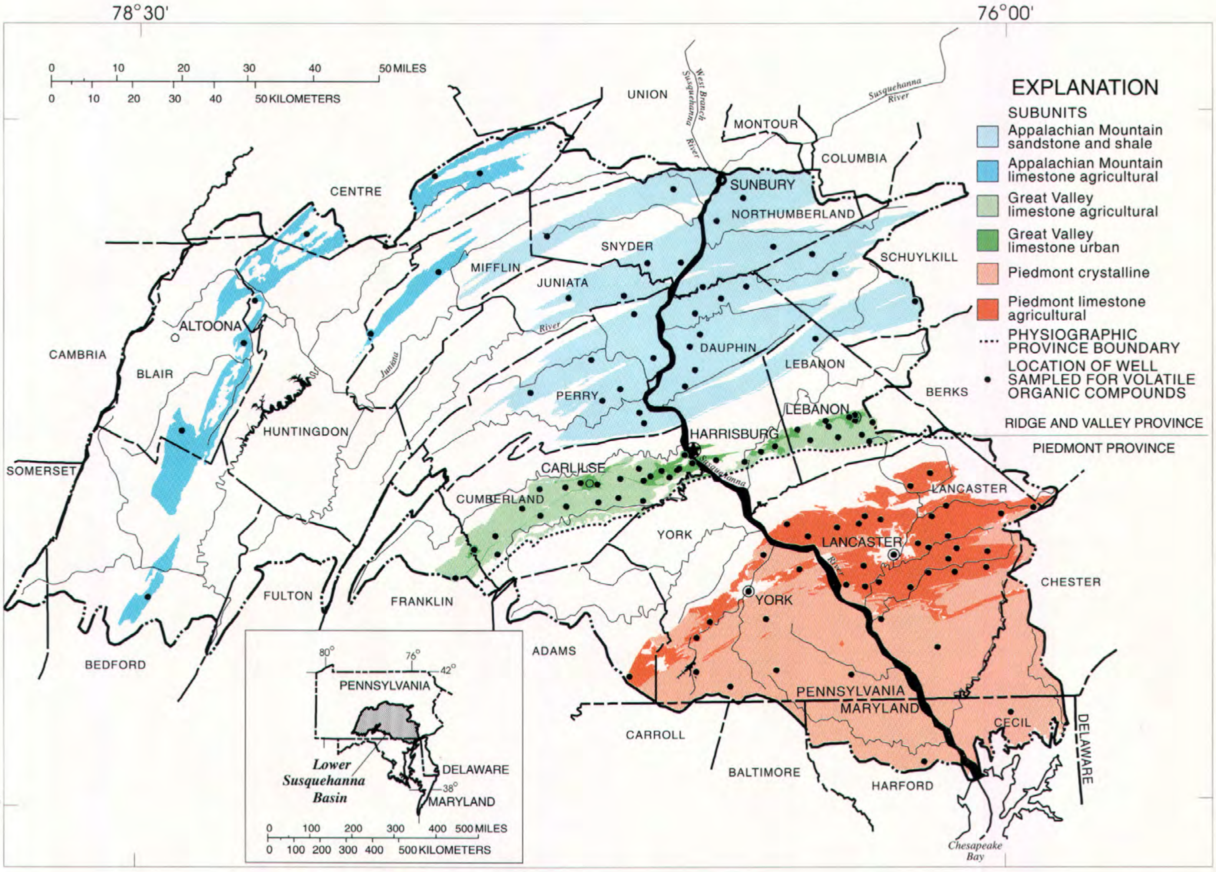

Figure 1. The Lower Susquehanna River Basin study unit and subunits where ground water was sampled and analyzed for volatile organic compounds.

Table 1. *Description of subunits studied in the Ridge and Valley and Piedmont Physiographic Provinces by the National Water-Quality Assessment Program, Lower Susquehanna River Basin study unit, Pennsylvania and Maryland*

	RIDGE AND VALLEY				PIEDMONT	
Physiographic section	APPALACHIAN MOUNTAIN		GREAT VALLEY		UPLAND	LOWLAND
Bedrock lithology	Sandstone and shale	Limestone and dolomite	Limestone and dolomite		Igneous and metamorphic	Limestone and dolomite
Land use (no. of wells sampled)	Agricultural (22) Forest (7)	Agricultural (9)	Agricultural (20)	Urban (20)	Agricultural (8) Suburban (1) Forest (1)	Agricultural (30)
Population density, per square mile[1]	110	53	290	1,300	210	410
Subunit name	Appalachian Mountain sandstone and shale	Appalachian Mountain limestone agricultural	Great Valley limestone agricultural	Great Valley limestone urban	Piedmont crystalline	Piedmont limestone agricultural

[1] Average population density of census block tracts whose centroids fall inside subunit boundary (U.S. Bureau of the Census, 1991a; 1991b).

Acknowledgments

The authors acknowledge the cooperation of the well owners for permitting access to sample their wells. The authors thank Kevin J. Breen for his assistance throughout the report-writing process and Diana L. Dugas for graphics support. In addition, the authors acknowledge J. Kent Crawford, William L. Cunningham, Manuel S. Nzambi, Dennis W. Risser, Albert T. Rutledge, Kim Shank, Ronald A. Sloto, Kim L. Wetzel, and John S. Zogorski as members of the report-preparation team.

METHODS

Within each subunit, potential sampling wells were identified with a computerized random selection program (Scott, 1990). Field visits were conducted to confirm land use and well construction. Wells that were less than 20 years old and less than 200 ft (feet) deep were selected to obtain samples representative of shallow ground-water conditions. In a few cases, slightly older or deeper wells were sampled. Of the 118 wells sampled, 99 were domestic wells used as drinking water supplies, 9 were other domestic wells not used as drinking water supplies, 9 were monitoring wells, and 1 was a public supply well. A detailed plumbing inspection of each supply well ensured that the sample was untreated water.

Samples of well water were obtained with submersible pumps (116 wells) and bailers (2 wells). A minimum of one well volume of water was purged prior to sampling. VOC samples were collected in 40 milliliter vials. Samples were immediately preserved with hydrochloric acid to a pH less than 2, chilled, and shipped within 24 hours to the laboratory for analysis. All samples were analyzed by the USGS National Water Quality Laboratory in Arvada, Colo. For each sample, 60 selected VOC's (Durlin and Schaffstall, 1994, p. 331) were analyzed by purge and trap capillary gas chromatography/mass spectrometry (Rose and Schroeder, 1995).

In addition to the 118 samples, 26 quality-assurance samples, including 14 blanks and 12 spikes, were analyzed to determine the reliability of the results. Five wells in the Great Valley limestone urban subunit also were resampled to confirm the presence of compounds. The quality-assurance program identified that the data collected were reliable and reproducible, with the following exceptions. Chloromethane was a contaminant in the preservation acid and 1,2,4-trimethylbenzene was a contaminant from an undetermined source. The detections of these compounds did not exceed the Maximum Contaminant Levels or the Lifetime Health Advisory Levels and are not discussed further in this report.

Concentrations of VOC's are reported in micrograms per liter (or parts per billion). For this report, the data are not censored to the reporting value of 0.2 µg/L (micrograms per liter), rather the method detection limit (MDL) for the individual compounds is used. The MDL is the minimum concentration of a substance that can be identified, measured, and reported with confidence (U. S. Environmental Protection Agency, 1984).

OCCURRENCE AND CONCENTRATIONS OF VOLATILE ORGANIC COMPOUNDS IN GROUND WATER

Twenty-four VOC's were detected in samples of well water from the six subunits. Of the 24 VOC's, 19 are either regulated, listed for regulation, or proposed to be regulated by the U.S. Environmental Protection Agency (1996). Although none of the concentrations of VOC's in drinking water wells exceeded the Maximum Contaminant Levels or Lifetime Health Advisory Levels, compounds linked to cancer and other adverse health effects were detected. The 1993-94 data are reported in Durlin and Schaffstall (1994; 1996) and the 1995 data are on file at the USGS office in Lemoyne, Pa. A summary of the occurrence of VOC's in each subunit and the number of wells sampled in the subunits is presented in table 2.

Wells in Five Rural Subunits

The combined areas of the five rural subunits represent approximately 42 percent of the land in the Lower Susquehanna River Basin study unit. The sampling results in these rural subunits provide an assessment of the spatial distribution of the occurrence of VOC's in ground water.

Samples of well water from the rural subunits show a range of occurrence of VOC's (table 2). Waters from the Appalachian Mountain Physiographic Section had the lowest frequency of occurrence of VOC's; detections ranged from 0 to 3 percent. The Piedmont subunits and the Great Valley limestone agricultural subunit had detections of VOC's ranging from 20 to 30 percent. The occurrence of VOC's may be related to the higher population densities in the Piedmont and Great Valley subunits relative to the Appalachian Mountain subunits (table 1). A study of ground water on Long Island, N.Y., demonstrated that VOC presence is related to population density (Eckhardt and Stackelberg, 1995).

Concentrations of 11 compounds were present in water from 16 of the 98 wells in the 5 rural subunits. Methyl *tert*-butyl ether was the most commonly detected compound, found in water from 6 of the 98 wells. 1,1,1 trichloroethane was detected in water from four wells, and trichloroethene, tetrachloroethene, and dichlorodifluoromethane were each present in water from

Table 2. *Summary of the occurrence of volatile organic compounds in ground water from wells in the subunits sampled by the National Water-Quality Assessment Program, Lower Susquehanna River Basin study unit, Pennsylvania and Maryland*

[VOC, volatile organic compound]

	Subunit name (number of wells sampled)					
	Appalachian Mountain sandstone and shale (29)	Appalachian Mountain limestone agricultural (9)	Great Valley limestone agricultural (20)	Great Valley limestone urban (20)	Piedmont crystalline (10)	Piedmont limestone agricultural (30)
Number of wells with at least one VOC detected	1	0	4	16	3	8
Percentage of wells with at least one VOC detected	3	0	20	80	30	27

two wells. The highest concentration detected in a rural subunit was 3.0 µg/L of 1,1,1-trichloroethane, which was detected in a water sample from the Great Valley limestone agricultural subunit. All of the VOC's detected in the rural areas were in water samples from domestic supply wells.

The VOC's in ground water from the rural subunits can be from point and nonpoint sources. One unique source in rural areas is from septic tanks. Commercial septic tank cleaning solutions contain VOC's, and studies from Viraraghavan and Hashem (1986) and Kolega and others (1987) have shown that VOC's can be detected in the effluents from septic tanks.

Wells in Urban and Agricultural Subunits in the Great Valley

The Great Valley extends more than 70 mi (miles) in the Lower Susquehanna River Basin from Shippensburg to Lebanon (fig. 2). Most of the urban and agricultural areas in the valley are underlain by limestone aquifers. The Great Valley subunits were studied to compare how agricultural and urban land use affects the water quality of the limestone aquifers. To determine the relation between VOC occurrence and land use, samples were collected and analyzed for VOC's at 20 wells in the urban subunit and 20 wells in the agricultural subunit.

Waters from wells in the urban subunit have a significantly higher occurrence (Chi-Square = 14.04, probability = 0.0002) of VOC's than waters from wells in the agricultural subunit (table 2). At least one VOC was detected in water from 80 percent of the wells in the urban subunit, and at least one VOC was detected in 20 percent of the waters from wells in the agricultural subunit.

The compounds detected, the MDL, the number of detections, and the maximum concentrations are shown in table 3. Analysis of water from wells in the urban subunit detected 22 compounds, and analysis of water from wells in the agricultural subunit detected 5 compounds. In the urban subunit, seven VOC's were detected at least three times. In the agricultural subunit, one VOC was detected three times.

Three of the urban wells were domestic supply wells, and one was a municipal water supply well. Of these four drinking supply wells, three had detectable concentrations of VOC's. Before distribution to individual houses, water from the municipal well is treated by air stripping to remove VOC's.

The most commonly detected compounds in the urban subunit were chloroform, methyl *tert*-butyl ether, tetrachloroethene, and 1,1,1-trichloroethane. Chloroform was detected in water from 13 of the 20 wells. Methyl *tert*-butyl ether was detected in water from 10 wells, tetrachloroethene in water from 9 wells, and 1,1,1 trichloroethane in water from 7 wells. These compounds have origins in gasoline products, chlorinated solvents, chlorinated waters, and wastewater.

The high occurrence of VOC's in ground water from wells in the urban subunit can be attributed to the sources of VOC's in urban areas. VOC's are widely and regularly used, stored, and transported in urban areas, so there is a high risk for accidentally or intentionally releasing the compounds to the ground water. VOC's can leach from landfills or open dumps, and stormwater runoff from paved areas can contain VOC's that can recharge ground water. All these sources potentially contribute VOC's to the aquifers in the Great Valley.

Another potential source of VOC's to the urban subunit might be precipitation. Urban areas have numerous airborne VOC's (Shah and Singh, 1988), and many of these compounds have been detected in rain water (Ligocki and others, 1985). This nonpoint source of contamination is thought to contribute trace concentrations of VOC's to recently recharged ground water in the uppermost part of an unconfined aquifer. Currently, it is uncertain if this process is an important source of VOC's to the ground water.

VOC's can readily move through the fractures and other openings that control ground-water flow in the Great Valley limestone aquifers. These fractures and water-filled caverns result in highly productive water-bearing zones that are ideal for water supplies. However, these zones allow contaminants to migrate readily from source areas to discharge areas in the aquifer.

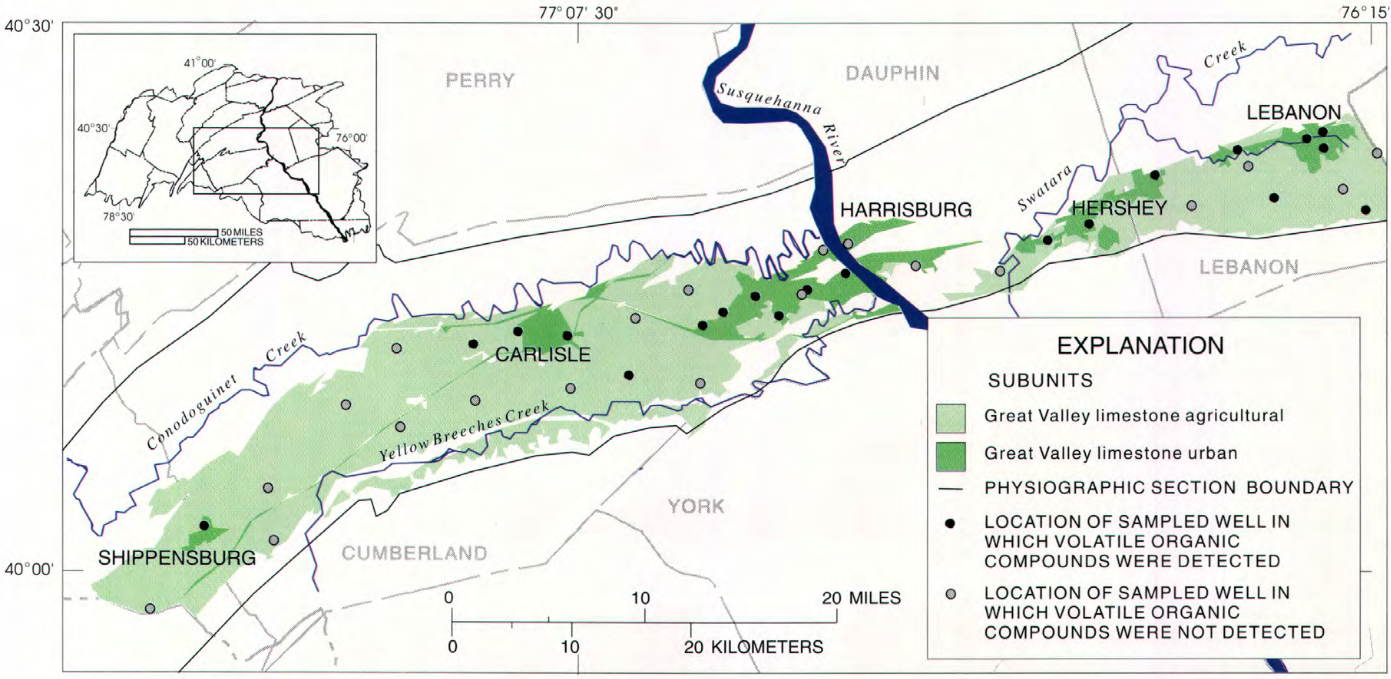

Figure 2. Wells sampled for volatile organic compounds in the Great Valley subunits, Lower Susquehanna River Basin study unit.

Table 3. *Volatile organic compounds in ground water from wells in the Great Valley subunits, Lower Susquehanna River Basin study unit, Pennsylvania and Maryland*

[n, number of wells sampled for volatile organic compounds; µg/L, micrograms per liter; <, less than]

Compound	Method detection limit (µg/L)	Urban subunit (n=20)		Agricultural subunit (n=20)	
		Number of detections	Maximum concentration (µg/L)	Number of detections	Maximum concentration (µg/L)
Benzene	0.06	2	4.4	0	<0.06
Bromodichloromethane	.06	3	3.5	0	<.06
Carbon tetrachloride	.09	1	.58	0	<.09
Chlorodibromomethane	.06	1	.38	0	<.06
Chloroform	.06	13	61	0	<.06
1,1-Dichloroethane	.06	2	.35	0	<.06
1,1-Dichloroethene	.08	0	<.08	1	.51
cis-1,2-Dichloroethene	.05	3	4.4	0	<.05
trans-1,2-Dichloroethene	.08	1	.11	0	<.08
Dichloromethane	.11	1	.41	0	<.11
Ethylbenzene	.08	2	5.4	0	<.08
Isopropylbenzene	.08	2	.78	0	<.08
p-Isopropyltoluene	.09	1	.26	0	<.09
Methylbenzene	.05	2	12	0	<.05
Methyl *tert*-butyl ether	.06	10	51	1	.11
Naphthalene	.06	2	1.8	0	<.06
n-Propylbenzene	.09	1	.63	0	<.09
Tetrachloroethene	.07	9	4.3	1	.11
1,1,1-Trichloroethane	.06	7	2.2	3	3.0
Trichloroethene	.16	4	2.7	1	2.0
Trichlorofluoromethane	.08	1	.10	0	<.08
1,3,5-Trimethylbenzene	.07	1	4.0	0	<.07
Xylenes (total)	.13	2	41	0	<.13

Wells, Springs, and Surface Water in the Cedar Run Basin

The hydrology of a watershed underlain by limestone aquifers provides further information on the occurrence of VOC's in the Great Valley limestone urban subunit. In eastern Cumberland County, the Cedar Run Basin drains 12.6 mi^2 of mostly urban land (fig. 3). Three tributaries and a main stem comprise the drainage network. On May 3, 1994, stream discharge at site 10, the streamflow-gaging station site near the mouth of Cedar Run, was 25.3 ft^3/s (cubic feet per second). As shown in figure 3, the tributary fed by spring CU-2 contributes 5.5 of the total 25.3 ft^3/s discharge (22 percent), the northern tributary fed by spring CU-35 adds 3.9 of the 25.3 ft^3/s discharge (15 percent), and the main stem delivers 15.9 of the 25.3 ft^3/s discharge (63 percent). The two northern tributaries are perennially fed by springs CU-2, CU-3, and CU-35, and the main stem also is fed by springs. Upstream from the springs, the flow of Cedar Run is intermittent. Ground-water flow is generally from west to east (Becher and Root, 1981). Sinkholes in the western part and springs in the eastern part of the basin (fig. 3) indicate general recharge and discharge areas, respectively.

The two northern tributaries drain urban land, and the main stem is influenced by urban and other land uses. The 1990 census recorded approximately 26,000 people in the basin and a population density of about 1,800 people per square mile (U.S. Bureau of the Census, 1991a; 1991b)

An accounting of the point sources of contamination in the Cedar Run Basin reveals a history of VOC releases. Since 1989, the Pennsylvania Department of Environmental Protection (PaDEP) has required the reporting of all known releases from underground storage tanks. From 1989 to 1993, 29 sites in the Cedar Run Basin reported such releases. The sources of compounds were leaks of gasoline, diesel fuel, and heating oil. Of the 29 sites investigated, 16 had soil contamination, and 5 sites were required to monitor the ground water. Four of these five sites had confirmed ground-water contamination. Also, there are an additional 13 sites in the basin that are related to abandoned landfills, solvent disposal areas, and other spills.

Prior to 1989, the only significant known release to affect the basin was the reported release of a large quantity of petroleum products west of Shiremanstown. As reported in Becher and Root (1981), by 1974 a total of 219,000 gallons of petroleum products were recovered from nearby surface pools, ditches, basements, and wells. The extent of the contamination was never fully determined, and it is still evident at tributary site 7 by the odor of gasoline and the detections of benzene, methylbenzene (toluene), ethylbenzene, and xylenes (total).

From 1994 to 1995, samples were collected from four monitoring wells, two springs, and four sites on Cedar Run during base-flow conditions. The results show VOC's in the ground water, and springs CU-3 and CU-35 are discharging the compounds into the two northern tributaries of Cedar Run. After entering the stream, the concentrations generally decrease because of dilution and the volatile nature of the compounds. Concentrations of several compounds were detected at site 10 near the confluence with the Yellow Breeches Creek.

Analyses of samples from the Cedar Run Basin indicated the presence of 23 VOC's. The widespread occurrence of chloroform, bromodichloromethane, tetrachloroethene, 1,1,1-trichloroethane, trichloroethene, and methyl *tert*-butyl ether is illustrated in table 4. Each compound was detected in at least 6 of the 12 samples. Chloroform and methyl *tert*-butyl ether were the most commonly occurring compounds, detected in 92 percent and 67 percent of the samples, respectively. Benzene, methylbenzene, ethylbenzene, xylenes (total), and methyl *tert*-butyl ether are compounds commonly associated with gasoline spills. All five of these compounds were found at two of the sites (well 3 and tributary site 7). Methyl *tert*-butyl ether was also detected at six other locations. Recent studies have shown that methyl *tert*-butyl ether is a commonly detected compound in ground water underlying urban areas (Squillace and others, 1995). The concentrations of VOC's in wells 3 and 4 vary in the two samples collected from each well.

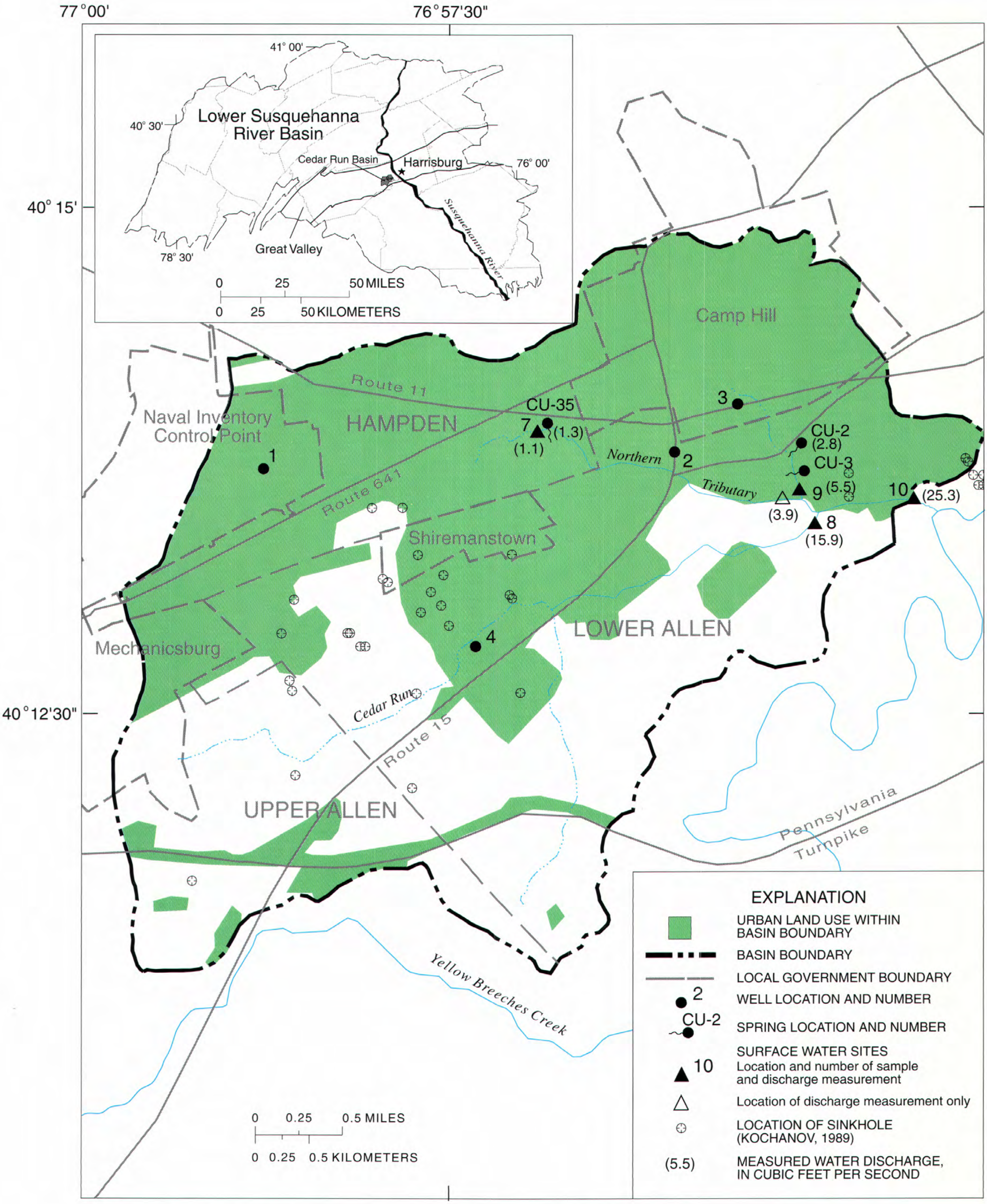

Figure 3. The Cedar Run Basin and water sampling locations, Lower Susquehanna River Basin study unit.

Table 4. *Concentrations of selected volatile organic compounds in water samples from the Cedar Run Basin, 1994-95*

[<, less than]

Compound	Concentration, in micrograms per liter											
									Cedar Run			
	Wells						Springs		Tributary sites			Gaging station site
	Site 1 7/18/95	Site 2 7/17/95	Site 3 9/20/94	Site 3 7/27/95	Site 4 8/11/94	Site 4 7/26/95	Site CU-3 9/7/95	Site CU-35 5/3/94	Site 7 5/3/94	Site 8 5/3/94	Site 9 5/3/94	Site 10 5/3/94
Benzene	<0.06	<0.06	0.21	<0.06	<0.06	<0.06	<0.06	<0.06	24	<0.06	<0.06	<0.06
Bromodichloromethane	.34	<.06	.14	<.06	.20	<.06	.28	.18	<.06	<.06	.12	<.06
Chloroform	13.0	<.06	2.5	3.0	2.1	.77	11.0	6.8	1.2	.42	2.5	.65
Ethylbenzene	<.08	<.08	.47	<.08	<.08	<.08	<.08	<.08	3.0	<.08	<.08	<.08
Methylbenzene	<.05	<.05	2.0	<.05	<.05	<.05	<.05	<.05	1.3	<.05	<.05	<.05
Methyl *tert*-butyl ether	.15	<.06	.78	.23	<.06	<.06	.33	1.4	7.8	<.06	.17	.19
Tetrachloroethene	1.7	<.07	.62	.54	.10	<.07	.90	.23	<.07	<.07	.61	<.07
1,1,1-Trichloroethane	.37	<.06	.30	.13	.10	<.06	.32	.17	<.06	<.06	.12	<.06
Trichloroethene	2.7	<.16	.23	.21	<.16	<.16	.21	1.0	.22	<.16	.20	<.16
Xylenes (total)	<.13	<.13	2.8	<.13	<.13	<.13	<.13	<.13	5.2	<.13	<.13	<.13

The presence of VOC's in the two northern tributaries (springs CU-3 and CU-35 and tributary sites 7 and 9) supports the findings of the Pennsylvania Department of Environmental Resources (PaDER) (Johnson, 1989). In addition, this study detected compounds in the southern tributary (site 8) and in the main stem near the mouth of Cedar Run (site 10). This study used lower detection limits than the PaDER study, so these compounds could have been present, but not detected, during the PaDER study. Concentrations of all compounds detected in the stream were less than acute and chronic water-quality criteria for the protection of aquatic life (Pennsylvania Department of Environmental Resources, 1994).

SUMMARY

Results from a regional assessment of VOC's in ground water by the USGS National Water-Quality Assessment program in the Lower Susquehanna River Basin study unit are reported. Ground water from 118 shallow wells, ranging from 30 to 226 ft deep and completed in unconfined fractured-bedrock aquifers, was sampled during 1993-95 and analyzed for 60 compounds. Six areas and aquifers were sampled including four in limestone, one in crystalline rocks, and one in interbedded sandstone and shale. The land use is rural in four of the areas. An urban and an agricultural (also rural) area near Harrisburg, Pa., in Cumberland, Dauphin, and Lebanon Counties also were studied to determine if the occurrence of VOC's in limestone aquifers is influenced by land use.

Analyses for VOC's at detection levels ranging from 0.05 to 0.2 µg/L reveal the presence of 24 compounds. The compounds were present in waters from 32 of the 118 wells. Concentrations of 11 compounds were detected in water from 16 of the 98 wells in the rural areas. Concentrations of 22 compounds were detected in water from 16 of the 20 wells in the urban area. Although none of the detections in samples from wells used as drinking water supplies exceeded any Maximum Contaminant Levels, the concentration of 51 µg/L of methyl *tert*-butyl ether in one water sample from a monitoring well is in the 20 to 200 µg/L range proposed for a Lifetime Health Advisory Level.

Methyl *tert*-butyl ether was the most commonly detected compound, found in 16 of the 118 wells. Concentrations of methyl *tert*-butyl ether ranged from 0.11 to 51 µg/L. Chloroform was the second most commonly detected compound, found in 14 of the 118 wells and 13 of the 20 wells in the urban area. The highest concentration detected in a water sample was 61 µg/L of chloroform.

The occurrence of VOC's in limestone aquifers in the Great Valley near Harrisburg, Pa., is influenced by land use. Occurrence of VOC's is higher in the urban area than in the agricultural area. At least one VOC was detected in water from 80 percent of the wells in the urban area, and at least one VOC was detected in 20 percent of the waters from wells in the agricultural area. Within the urban area, 23 VOC's were present in water samples from wells, springs, and stream sites in the Cedar Run Basin. Springs are discharging contaminated ground water into the northern tributaries of Cedar Run. Detectable concentrations of compounds are present in the stream above the confluence with the Yellow Breeches Creek.

For additional information, contact:
District Chief
U.S. Geological Survey, WRD
840 Market Street
Lemoyne, Pennsylvania 17043-1586
(717) 730-6913

REFERENCES

Anderson, J.R., Hardy, E.E., Roach, J.T., and Witmer, R.E., 1976, A land use and land cover classification system for use with remote sensor data: U.S. Geological Survey Professional Paper 964, 28 p.

Becher, A.E., and Root, S.I., 1981, Groundwater and geology of the Cumberland Valley, Cumberland County, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Water Resource Report 50, 95 p., 3 plates.

Durlin, R.R., and Schaffstall, W.P., 1994, Water resources data, Pennsylvania, water year 1993, vol. 2, Susquehanna and Potomac River Basins: U.S. Geological Survey Water-Data Report PA-93-2, 361 p.

_____1996, Water resources data, Pennsylvania, water year 1994, vol. 2, Susquehanna and Potomac River Basins: U.S. Geological Survey Water-Data Report PA-94-2, 418 p.

Eckhardt, D.A.V., and Stackelberg, P. E., 1995, Relation of ground-water quality to land use on Long Island, New York: Ground Water, v. 33, no. 6, p. 1019-1033.

Gilliom, R.J., Alley, W.M., and Gurtz, M.E., 1995, Design of the National Water-Quality Assessment Program—Occurrence and distribution of water-quality conditions: U.S. Geological Survey Circular 1112, 33 p.

Johnson, G.D., 1989, Cedar Run - Special protection evaluation report: Water Quality Standards Review, Pennsylvania Department of Environmental Resources, Bureau of Water-Quality Management, 25 p.

Kochanov, W.E., 1989, Sinkholes and karst-related features of Cumberland County, Pennsylvania: Pennsylvania Geological Survey, Open File Report 89-02, 8 p., 9 map sheets.

Kolega, J.J., Hill, D.W., and Laak, R., 1987, Contribution of selected toxic chemicals to ground water from domestic on-site sewage disposal systems, *in* Focus on Eastern Regional Ground Water Issues-A Conference, Burlington, Vt., July 14-16, 1987, [Proceedings], p. 279-289.

Ligocki, M.P., Leuenberger, C., and Pankow, J.F., 1985, Trace organic compounds in rain—II. Gas scavenging of neutral organic compounds: Atmospheric Environment, v. 19, no. 10, p. 1609-1617.

Pennsylvania Department of Environmental Resources, 1994, Water quality toxics management strategy: Bureau Of Water Quality Management, Division of Assessment and Standards, Pennsylvania Code Title 25., Chapter 16, 42 p.

Risser, D.W., and Siwiec, S.F., in press, Water-quality assessment of the Lower Susquehanna River Basin, Pennsylvania and Maryland—Environmental setting: U.S. Geological Survey Water-Resources Investigations Report, 94-4245, 135 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.

Scott, J.C., 1990, Computerized stratified random site-selection approaches for design of a ground-water- quality sampling network: U.S. Geological Survey Water-Resources Investigations Report 90-4101, 109 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., Pope, D.A., and Price, C.V., 1995, Occurrence of the gasoline additive MTBE in shallow ground water in urban and agricultural areas: U.S. Geological Survey Fact Sheet FS-114-95, 4 p.

U.S. Bureau of the Census, 1991a, Census of population and housing, 1990: Public Law 94-171 data (United States) [machine-readable data files]: Washington, D.C., The Bureau [producer and distributor].

_____1991b, TIGER/Line Census Files, 1990 [machine-readable data files]: Washington, D.C., The Bureau [producer and distributor].

_____1992, Census of population and housing, 1990: Washington, D. C., Summary tape file 3 on CD-ROM [machine-readable data files].

U.S. Environmental Protection Agency, 1984, Definition and procedure for determination of the method detection limit, Revision 1.11, Appendix B to part 136, Federal Regulations 1984; 49 (209); 43430.

_____1996, Drinking water regulations and health advisories: Office of Water, EPA 822-R-96-001, Washington, D.C., 16 p.

Viraraghavan, T., and Hashem, S., 1986, Trace organics in septic tank effluents: Water, Air, and Soil Pollution, v. 28, no. 3-4, p. 299-308.

Copies of this report may be purchased from:
U.S. Geological Survey
Branch of Information Services
Box 25286
Denver, Colorado 80225-0286

For additional information about USGS programs and activities in Pennsylvania, please visit our web site at:
http://wwwpah2o.er.usgs.gov/