NATIONAL WATER-QUALITY ASSESSMENT PROGRAM

Shallow Ground-Water Quality in the Coastal Plain of Columbia, South Carolina, 1996

Significant Findings

- Nitrate was detected in 26 of 30 wells, but all concentrations were below the U.S. Environmental Protection Agency maximum contaminant level of 10 mg/L for drinking water.
- Pesticides were detected in 22 of 30 wells.
- Atrazine, deethyl atrazine, simazine, and dieldrin were the most commonly detected pesticides.
- Volatile organic compounds were detected in 27 of 30 wells, and 2 wells had 15 different volatile organic compounds.
- Chloroform was detected in 21 wells. Other volatile organic compounds occurring in more than 5 wells include chloromethane, dichlorobromomethane, benzene, 1,1,1-trichloroethane, iodomethane, trichloroethylene, tetrachloroethylene, 1,1-dichloroethane, dichloromethane, 4-isopropyl-1-methylbenzene, methyl tert-butyl ether, and acetone.
- Methyl tert-butyl ether and trichloroethylene exceeded the U.S. Environmental Protection Agency maximum contaminant levels once each in two different wells.

Introduction

As part of the National Water-Quality Assessment (NAWQA) Program, the U.S. Geological Survey (USGS) oversaw the installation of 30 shallow monitoring wells in the Columbia, South Carolina metropolitan area (fig. 1). The ground water sampled from these wells was used to study the recent effects of human activities on shallow ground water in an urban setting. Well locations were selected in residential and commercial areas constructed between 1960 and 1990 while all industrial and agricultural areas were avoided. Samples were collected and analyzed for major ions, nutrients, pesticides, and volatile organic compounds (VOCs) during 1996. This report describes the results of this investigation of shallow ground-water quality.

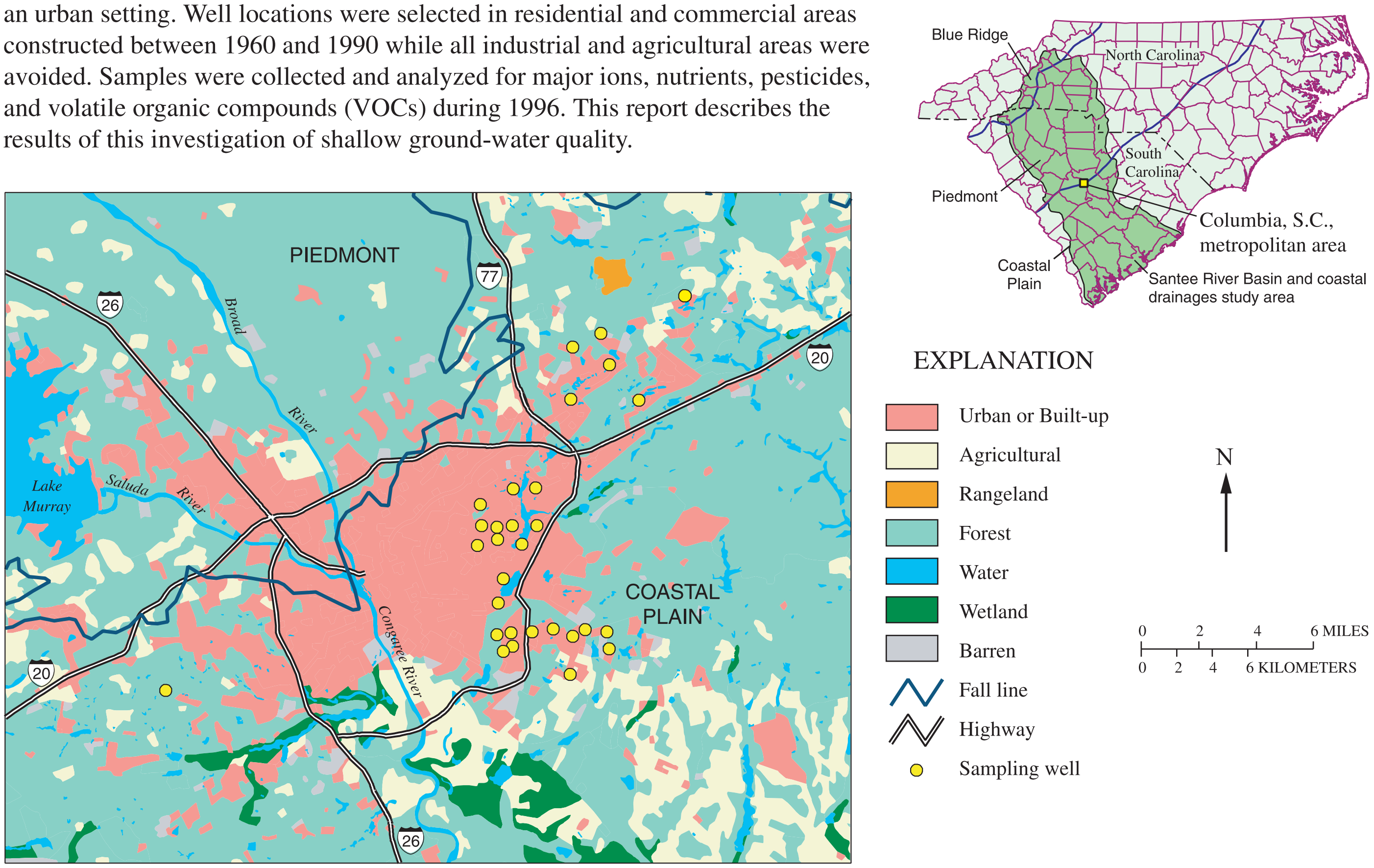

Figure 1. Location of study area, wells sampled, and land uses.

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Description of Columbia Metropolitan Area

The Columbia metropolitan area includes the city of Columbia and multiple surrounding suburban communities. The metropolitan area has a population exceeding 400,000 (Central Midlands, Council of Governments, 1998), is growing rapidly, and experienced a 15-percent increase in population between 1980 and 1997. The majority of urban growth in the Coastal Plain has occurred since 1960 in the form of commercial and residential development east of Columbia along Interstates 77 and 20. The metropolitan area overlies both the Piedmont and Coastal Plain and is divided by the Fall Line (fig. 1). This study included only areas in the Coastal Plain. The high permeability and shallow water table of the Coastal Plain's sandy sediments make Columbia's shallow ground water vulnerable to contamination by human activities.

Average rainfall in the Columbia metropolitan area is about 50 inches per year (South Carolina Water Resources Commission, 1983). Hydrogeologic units in the shallow ground-water zone consist of interbedded sand and clay. Water levels in monitoring wells measured during the study ranged between about 1 and 50 feet (ft) below land surface.

Why Is Ground-Water Quality Important?

Presently, surface water, instead of ground water, is used for most public water supplies in the metropolitan area. However, ground water provides year-round discharge to surface water and potentially transports contaminants that can result in water-quality problems in streams and lakes (fig. 2). Consequently, the health of aquatic organisms and surface-water supplies can be affected by the chemical quality of shallow ground water discharged to streams and reservoirs. Several streams in the metropolitan area are noted to have high concentrations of nutrients and pesticides (Maluk, 1999). Shallow ground water that does not discharge to streams moves to deeper aquifers or is lost to evapotranspiration. Some smaller communities and private residences in the Columbia area use wells that obtain water from the deeper aquifers.

A ground-water-quality problem can render individual and community water supplies unusable for long periods. Ground water often moves slowly and does not mix well, causing some chemicals to persist in ground water for decades. Elevated concentrations of bacteria, dissolved minerals, and manmade chemicals, such as pesticides, solvents, and gasoline-related compounds are common ground-water-quality problems in urban and suburban areas. The difficulty and high cost of cleaning up contaminated sites or treating contaminated water make prevention of contamination the preferred means of effectively protecting ground-water quality.

Site Selection and Well Installation

Land-use practices in commercial and residential areas include use of pesticides, fertilizers, and other chemicals. Site selection was concentrated on residential and commercial areas developed between 1960 and 1990 in the eastern and northeastern parts of the Columbia metropolitan area (fig. 1, table 1). Areas developed after 1990 were not included in this study because of the time necessary for new construction to affect the ground-water system (Squillace and Price, 1996). Downtown Columbia also was excluded because urban land use in this area predates 1960 and water-quality results would be difficult to interpret. Industrial areas were not selected because other agencies are studying these areas, primarily to investigate point sources of contamination.

Thirty well sites were randomly selected based upon the above criteria using a computer program developed for the NAWQA (Scott, 1990). With the help of the Geological Survey of the South Carolina Department of Natural Resources, 30 shallow monitoring wells were installed according to NAWQA protocols (Lapham and others, 1995). Each well was completed with flush-threaded 2-inch-polyvinyl-chloride casing and screen.

Table 1. Ranges of land use around wells*
[*Individual areas within a 500-m radius of each well]

Land use	Percentage
Residential	36-97
Forest	0-44
Commercial	0-24
Wetlands	0-22
Agricultural	0-13

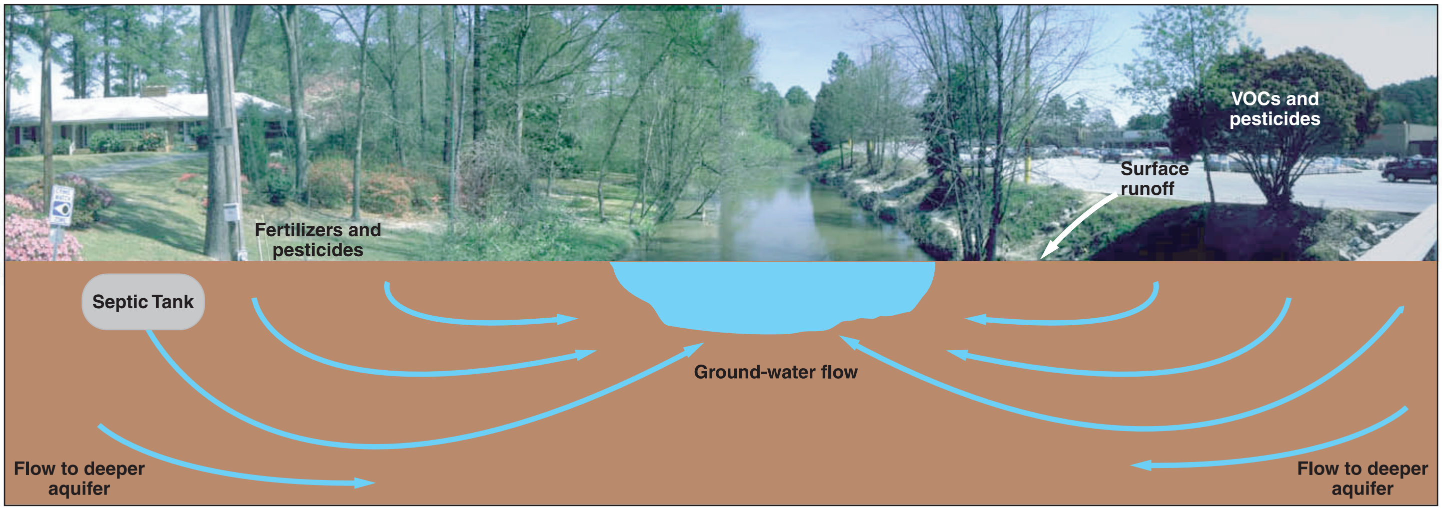

Figure 2. Potential movement of contaminants through ground water.

All wells have either a 5- or 10-ft screen at or near the water table and were finished according to South Carolina Department of Health and Environmental Control (SCDHEC) regulations (1985). Well depths ranged from 9 to 54 ft, and water levels ranged from about 1 to 50 ft below land surface.

Proper sampling protocols were followed to obtain and evaluate accurate water-quality data (Koterba and others, 1995). Water-quality samples were collected and preserved in the field and then shipped to the USGS National Water Quality Laboratory (NWQL) for analysis. To meet established water-quality objectives and to support USGS water-quality investigations, the NWQL provided broad spectrum, low-level analyses for pesticides and VOCs (Connor and others, 1998).

Chemicals Detected in Shallow Ground Water

In the Coastal Plain of South Carolina, shallow ground water contains dissolved ions and has physical properties that can be related to its distance from the recharge area. Recently recharged ground water contains high concentrations of dissolved oxygen, low pH and specific conductance, and low concentrations of dissolved ions as compared to older ground water (Back and others, 1988). Dissolved oxygen decreases and pH, specific conductance, and dissolved ions increase as minerals are dissolved by ground water moving through sediment. Measurement of these constituents and ions allows some understanding of how recently the water entered the aquifer and how it has interacted with the minerals in the aquifer.

The chemical composition of shallow ground water in the Columbia metropolitan area varies considerably. The pH values ranged from 4.3 to 5.9, with a median of 4.9, which are typical of recently recharged rain water. The pH values fall outside of the U.S. Environmental Protection Agency (U.S. EPA) secondary maximum contaminant level (SMCL) of 6.5 to 8.5 (U.S. Environmental Protection Agency, 1996a). SMCLs are standards set for aesthetic purposes and are not health based. Dissolved-oxygen concentrations ranged from 0.5 to 8.1 milligrams per liter (mg/L). Major ion concentrations, including calcium, magnesium, potassium, and sodium, were typical of shallow ground water in the Coastal Plain (table 2).

Nutrients

The nutrients, phosphorous and nitrogen, can occur naturally in ground water, but concentrations above background levels may be associated with human activities. Common sources are fertilizer and animal and human waste. Infiltration of septic-system effluent in residential areas can result in elevated nutrient levels. Leaching of fertilizers from nearby lawns or gardens also can result in elevated phosphorous and nitrogen concentrations in ground water.

The median concentration of nitrite plus nitrate nitrogen detected in the shallow ground water was 0.69 mg/L, and detectable concentrations were observed in 26 of 30 wells (table 2, fig. 3). Drinking water with high nitrate concentrations is a potential health risk. All concentrations of nitrate were below the U.S. EPA (1996b) maximum contaminant level (MCL) for nitrate in water of 10 mg/L. However, some concentrations were detected as high as 8 mg/L, indicating a possible anthropogenic influence. Dissolved phosphorous and orthophosphate concentrations were low in shallow ground-water samples from the study area, as is typical of most ground water.

Table 2. Summary of major ions and nutrient detections for 30 monitoring wells

[Units are milligrams per liter]

Constituent	Number of detections	Minimum concentration	Median concentration	Maximum concentration
Major ions				
Calcium	30	0.4	1.4	5.20
Sodium	30	0.8	4.7	18.0
Magnesium	30	0.14	0.71	1.50
Potassium	30	0.1	0.8	2.8
Sulfate	30	0.10	0.95	14.0
Chloride	30	1.6	7.7	18.0
Fluoride	1	0.1	0.1	0.1
Silica	30	5.10	6.35	12.0
Carbon				
Dissolved organic carbon	30	0.40	4.75	120
Nutrients				
Nitrogen, nitrite	10	0.01	0.01	0.03
Nitrogen, nitrite plus nitrate	26	0.07	0.69	8.00
Nitrogen, ammonia	21	0.02	0.03	2.50
Nitrogen, ammonia plus organic	5	0.2	0.2	2.8
Phosphorus	5	0.01	0.01	0.05
Phosphorus orthophosphate	3	0.01	0.01	0.06

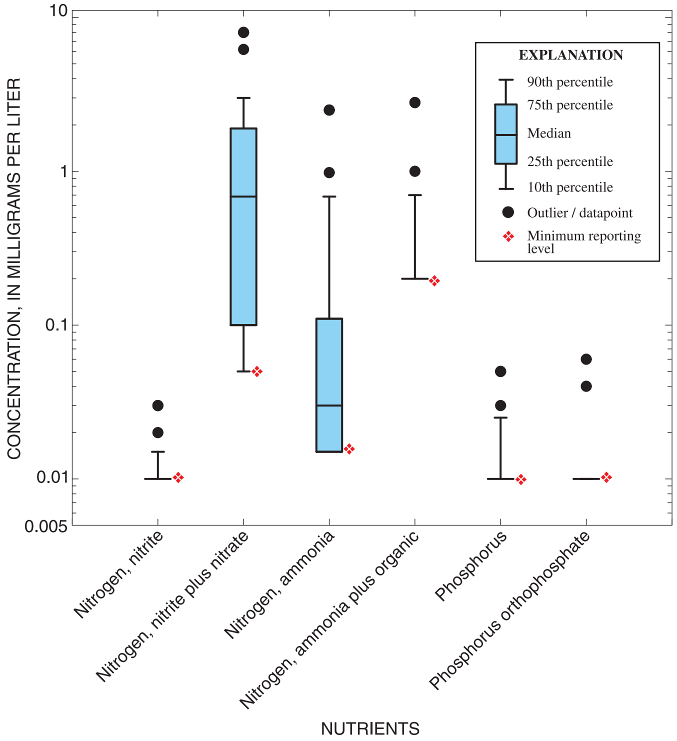

Figure 3. Nutrients detected for 30 monitoring wells.

High levels of nitrate in well water typically indicate an anthropogenic source, such as septic-tank effluent, animal wastes, fertilizers, municipal landfills, or other nonpoint sources. Nitrate contamination can cause damage to the spleen and methemoglobinemia, or “blue-baby syndrome.” Nitrate is also an environmental concern as a potential source of nutrient enrichment in lakes, streams, and wetlands.

Pesticides

Pesticides, including insecticides, herbicides, and fungicides, historically have been used in agricultural areas to control weeds and insects. However, the amount and type of pesticides used in suburban areas has changed because of the growth of the lawn care industry and the development of new herbicides and insecticides. In urban and suburban areas, pesticides are applied on lawns, golf courses, business parks, gardens, parks, and cemeteries in order to control or restrict insects and weeds. Herbicides are used to control vegetation around parking lots, fencelines, rights-of-way, and in swimming pools and ponds. Each use is a possible source of pesticide contamination of the shallow aquifer.

Table 3. Summary of pesticide detections for 30 monitoring wells

[Units are micrograms per liter; --, no applicable standard]

Constituent	Number of detections	Maximum concentration	Minimum reporting level	Lifetime HAL^{a,b}	MCL^{a,c}	Cancer group^{e}
Herbicides						
Atrazine	17	0.187	0.001	3	3	C
Deethyl atrazine	13	0.049	0.002	--	--	--
Simazine	12	0.049	0.005	4	4	C
Prometon	2	0.053	0.018	100^{d}	--	D
Tebuthiuron	2	0.521	0.01	500	--	D
Bentazon	1	0.140	0.014	200	--	D
Diuron	1	0.110	0.02	10	--	D
Bromacil	1	1.200	0.035	90	--	C
Norflurazon	1	0.440	0.024	--	--	--
Insecticides						
Dieldrin	7	0.941	0.001	--	--	B2
Diazinon	3	0.014	0.002	0.6	--	E
Chlorpyrifos	2	0.004	0.004	20	--	D
Carbaryl	2	0.005	0.003	700	--	D

[a] U.S. Environmental Protection Agency drinking water regulations and health advisories (1996a).

[b] Drinking Water Health Advisory Limit (HAL). The concentration of a chemical in drinking water that is not expected to cause any adverse noncarcinogenic effects over a lifetime of exposure, with a margin of safety.

[c] Maximum Contaminant Level (MCL). Maximum permissible level of a contaminant in water which is delivered to any user of a public water system (U.S. Environmental Protection Agency, 1996a)

[d] Under review.

[e] Cancer Group: B2- Probable human carcinogen, sufficient evidence from animal studies; C- Possible human carcinogen; D- Not classifiable; E- No evidence of carcinogenicity for humans (U.S. Environmental Protection Agency, 1996a)

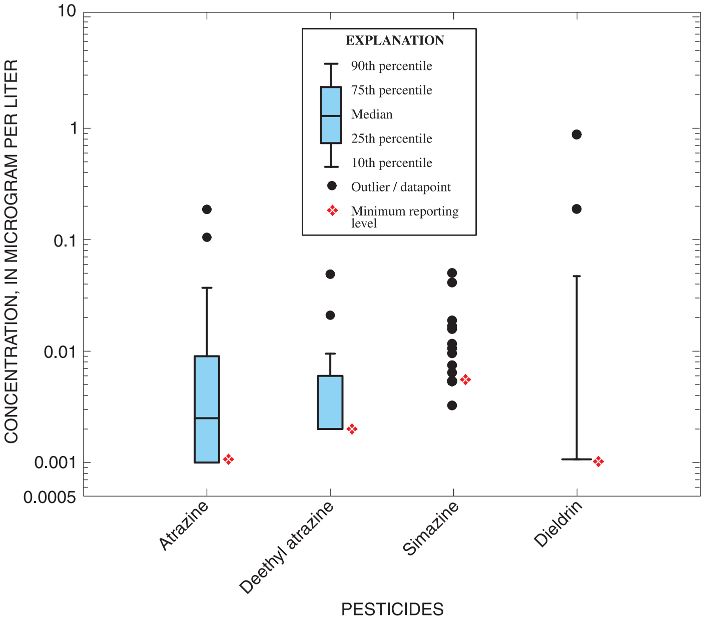

Figure 4. Most commonly detected pesticides for 30 monitoring wells.

Thirteen of 86 pesticides analyzed for were detected in samples from 22 of the 30 wells, with as many as 4 different pesticides detected in a single well. One reason for the high number of detections is the use of new analytical methods with low minimum reporting limits (Zaugg and others, 1995). The most frequently detected pesticides were atrazine, deethyl atrazine, simazine, and dieldrin (table 3 and fig. 4). The pesticides detected at the highest concentrations include bromacil, dieldrin, tebuthiuron, norflurazon, and atrazine (table 3). Drinking-water regulations and/or health advisories have been established for 11 of the 13 detected pesticides (U.S. Environmental Protection Agency, 1996a). The concentrations of pesticides which have MCLs are at least one order of magnitude below the applicable MCL.

The U.S. EPA has determined that exposure to certain pesticides in drinking water in excess of the MCL for a prolonged period of time can cause cancer as well as damage to various organs in the human body. In 1974, the U.S. EPA banned all uses of dieldrin except to control termites; then in 1987, dieldrin was banned for all uses. Because dieldrin, a carcinogen, is persistent in the environment, it is still detected at elevated concentrations (Agency for Toxic Substance and Disease Registry, 1998).

Volatile Organic Compounds (VOCs)

VOCs are components of petroleum products and are commonly used as metal degreasers, solvents, refrigerants, and cleaning compounds. VOCs also are present in fuels and in exhaust from fuel combustion. Direct industrial and wastewater discharges, accidental fuel and oil spills, and chlorinated municipal drinking water supplies are likely sources of VOCs in ground water. VOCs in rainfall may originate from vehicle and industrial emissions. Stormwater runoff and direct infiltration to the soil introduce the aquifer to another possible source of VOCs. Varied and widespread use of VOCs, as well as the possibility of atmospheric deposition, makes it difficult to relate a particular land use to a specific compound.

VOCs were detected in water samples from 27 of the 30 wells, with as many as 15 different VOCs detected at a single well. Thirty-five of 92 VOCs analyzed for were detected in samples from the 30 wells. Detection of several VOCs was the result of improved analytical techniques which measure low concentrations (Connor and others, 1998). The most frequently detected VOC was chloroform, occurring in 21 of 30 wells. VOCs occurring in more than 10 wells were chloroform, chloromethane, dichlorobromomethane, benzene, and 1,1,1-trichloroethane (table 4 and fig. 5). Other VOCs occurring in 6 to 10 wells include iodomethane, trichloroethylene (TCE), tetrachloroethylene, 1,1-dichloroethane, dichloromethane, 4-isopropyl-1-methylbenzene, methyl tert-butyl ether (MTBE), and acetone. The five VOCs detected with the highest concentrations include MTBE, TCE, acetone, tert-pentyl methyl-ether, and chloroform (table 4). Fifteen of the 35 detected VOCs have established drinking water standards. Of these 21 VOCs, only TCE and MTBE exceeded their established MCLs.

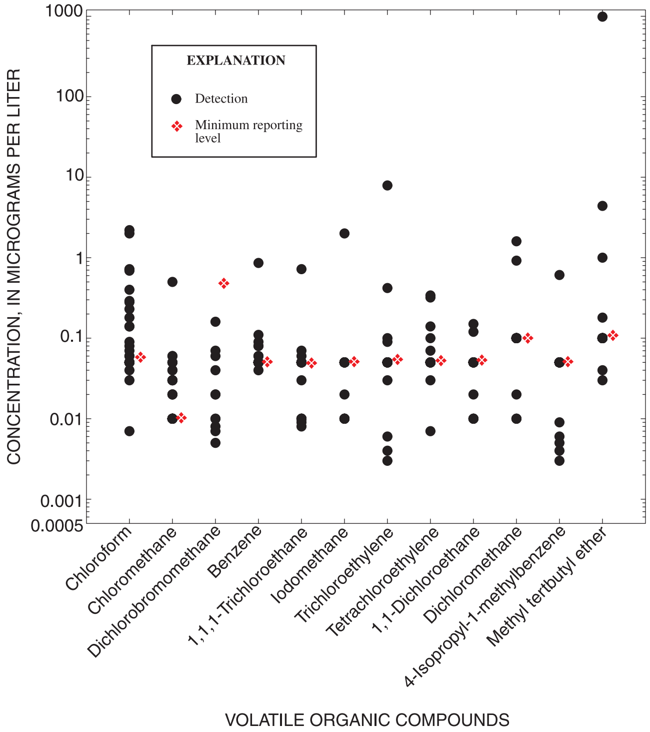

Figure 5. Most commonly detected volatile organic compounds for 30 monitoring wells.

Table 4. Summary of volatile organic compound detections for 30 monitoring wells

[Units in micrograms per liter; --, no applicable standard; *, Current MCL (U.S. Environmental Protection Agency, 1996a); +, 1994 Proposed rule for disinfectants and disinfection byproducts; total for all THMs combined cannot exceed the 80 µg/L level; Values in red exceed the current MCL and lifetime HAL]

Constituent	Number of detections	Maximum concentration	Minimum reporting level	Lifetime HAL[a,b]	MCL[a,c]	Cancer group[f]
Chloroform	21	2.20	0.05	--	100*/80+	B2
Chloromethane	18	0.50	0.01	--	--	--
Dichlorobromomethane	11	0.16	0.50	--	100*/80+	B2
Benzene	11	0.86	0.05	--	5	A
1,1,1-Trichloroethane	11	0.72	0.05	200	200	D
Iodomethane	10	2.00	0.05	--	--	--
Trichloroethylene	9	7.90	0.05	--	5	B2
Tetrachloroethylene	8	0.34	0.05	--	50	--
1,1-Dichloroethane	7	0.15	0.05	--	--	--
Dichloromethane	7	1.6	0.1	--	--	--
4-Isopropyl-1-methylbenzene	7	0.61	0.05	--	--	--
Methyl tert-butyl ether	7	987	0.1	20-200	20-40[e]	C
Acetone	6	6.0	5.0	--	--	--
1,1-Dichloroethylene	5	0.3	0.1	75	75	--
Cis-1,2-dichloroethene	5	0.08	0.05	--	--	--
Chlorobenzene	4	0.004	0.050	--	--	--
Trichlorofluoromethane	4	0.93	0.10	--	--	--
Iso-propylbenzene	3	0.19	0.05	--	--	--
Toluene	2	0.07	0.05	1,000	1,000	--
1,2-Dichloroethane	2	0.51	0.05	--	5	B2
1,2-Dichloropropane	2	0.008	0.050	--	5	B2
Vinyl chloride	2	0.05	0.10	--	2	A
Tert-pentyl methyl-ether	2	5.4	0.10	--	--	--
Methyl ethyl ketone[d]	2	1.0	5.0	--	--	D
Chloroethane	1	0.02	0.10	--	--	B
Ethylbenzene	1	0.01	0.05	700	700	D
Methyl bromide	1	0.10	0.05	--	--	--
1,2-Dichlorobenzene	1	0.007	0.050	600	600	D
1,2-Transdichloroethene	1	0.01	0.05	100	100	D
1,3-Dichlorobenzene	1	0.005	0.050	--	--	--
O-Oxylene	1	0.01	0.05	--	--	--
Sec-butylbenzene	1	1.40	0.05	--	--	--
Tert-butylbenzene	1	0.11	0.05	--	--	--
Diethyl ether	1	0.12	0.10	--	--	--
Tetrahydrofuran	1	2.1	5.0	--	--	--

[a] U.S. Environmental Protection Agency drinking water regulations and health advisories (1996a).

[b] Drinking Water Health Advisory Limit (HAL). The concentration of a chemical in drinking water that is not expected to cause any adverse noncarcinogenic effects over a lifetime of exposure, with a margin of safety.

[c] Maximum Contaminant Level (MCL). Maximum permissible level of a contaminant in water which is delivered to any user of a public water system (U.S. Environmental Protection Agency, 1996a).

[d] Under review.

[e] U.S. Environmental Protection Agency; FACT SHEET Drinking Water Advisory: Consumer Acceptability Advice and Health Effects Analysis on Methyl Tertiary-Butyl Ether (MtBE); EPA-822-F-97.

[f] Cancer group: A- Human carcinogen; B- Probable human carcinogen; B1- Probable human carcinogen, limited epidemilogic studies; B2- Probable human carcinogen, sufficient evidence from animal studies; C- Possible human carcinogen; D- Not classifiable (U.S. Environmental Protection Agency, 1996a).

Drinking water containing high levels of VOCs may be harmful to human health. The U.S. EPA estimates that VOCs are present in one-fifth of the Nation’s water supplies. Exposure to VOC-contaminated drinking water can cause cancer as well as damage to the lungs, liver, kidneys, and central nervous and circulatory systems. TCE and MTBE also have been labeled as probable and possible human carcinogens, respectively (U.S. Environmental Protection Agency, 1998).

—*Eric J. Reuber*

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NAWQA Program Information

The USGS is conducting an assessment of water quality in the Santee River Basin and coastal drainages (SANT) study area as part of the National Water-Quality Assessment (NAWQA) Program. The long term goals of NAWQA are to describe the status of and trends in the quality of a large representative part of the Nation's surface- and ground-water resources and to identify major factors that affect the quality of these resources. More than 50 hydrologic systems are to be studied that include parts of most major river basins and aquifer systems in the Nation. The assessment activities in the SANT study area began in 1994.

For More Information

Information on technical reports and hydrologic data related to the NAWQA Program can be obtained from:

District Chief
U.S. Geological Survey
Stephenson Center-Suite 129
720 Gracern Road
Columbia, SC 29210-7651

URL: *http://wwwsc.er.usgs.gov*

Additional information on health effects of nutrients, pesticides, or VOCs and drinking water and drinking water regulations can be obtained by calling the U.S. EPA's Safe Drinking Water Hotline 1-800-426-4791 or the South Carolina Department of Health and Environmental Control (SCDHEC), Bureau of Water information line 803-734-5300.