Volatile Organic Compounds in Ground Water from Rural Private Wells

Although we found that most private wells did not contain any VOCs, this assessment is a first step in better understanding the state of water quality from rural private wells.

By Michael Moran and Pixie Hamilton

The U.S. Geological Survey's (USGS) National Water-Quality Assessment (NAWQA) Program collected or compiled data on ground water from 1926 private wells in rural areas across the United States from 1986 to 1999. These private wells, also called domestic wells, are owned and operated by the homeowners and provide water for household uses, including drinking, food preparation, watering lawns and gardens, bathing, and washing clothes. The samples from these wells were analyzed for 55 volatile organic compounds (VOCs).

VOCs are important to study because they have been produced and used in a variety of commercial and industrial applications for many decades, and some VOCs are found in a variety of household products. VOCs have properties that allow them to move freely between the atmosphere, soil, surface water, and ground water. Some VOCs have federally established drinking water standards or health criteria.

This article summarizes the results of a NAWQA study on VOCs in private wells (Moran et al. 2002). This study is important because: (1) few studies have examined the presence of VOCs in private wells; (2) many of these compounds have human health concerns in drinking water; and (3) VOCs have been detected widely in ground water resources including public water supplies.

Although most private wells in this study did not contain any VOCs, this assessment is a first step in better understanding the state of water quality from rural private wells. This study will help identify current contamination issues associated with private wells and provide additional information that is needed to better protect this critical resource from contamination.

VOC Contamination in Private Wells

Of the 1926 private wells sampled, one or more VOCs were detected in 232 wells, or about 12 percent (Figure 1). This 12 percent detection frequency in rural private wells is lower than in public supply wells sampled by NAWQA, where 26 percent had one or more VOCs detected. The higher detection frequency of VOCs in public supply wells is likely a result, in part, of the higher pumping rates and larger areas contributing recharge to public supply wells compared to private wells.

Solvents and trihalomethanes were the most frequently detected types of VOCs. Gasoline oxygenates, refrigerants, gasoline hydrocarbons, fumigants, and chemicals used in organic synthesis were detected less frequently. No individual VOC was detected in more than 5 percent of the wells (Figure 2).

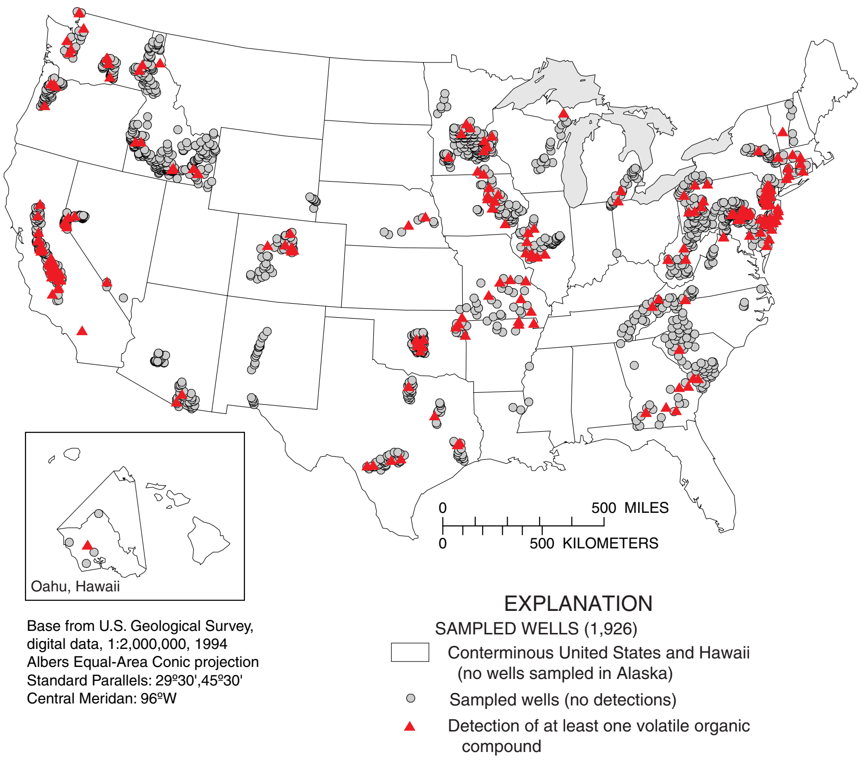

Figure 1. Location of rural, untreated, self-supplied private wells that were sampled for this study, and the location of wells where at least one volatile organic compound was detected.

Trichloromethane (chloroform) was detected in 4.3 percent of the wells. Other VOCs with detections in more than 1 percent of the wells included methyl *tert*-butyl ether (MTBE), tetrachloroethene (PCE), dichlorodifluoromethane, 1,1,1-trichloroethane, methylbenzene (toluene), and 1,2-dibromo-3-chloropropane (DBCP). The VOCs that were detected most frequently represent VOCs with many different consumer uses.

Private wells with detections of VOCs occurred in 31 of the 39 states from where samples were collected. It appears that the distribution of some VOCs in ground water is related to their geographic patterns of use. Although the locations of many private wells with detections of one or more VOCs are not geographically clustered, detections of gasoline oxygenates and fumigants appear to have geographic patterns of distribution that correspond to areas where these chemicals are used most intensively. Gasoline oxygenates were detected in five of 18 states with large areas that have participated in federal programs where oxygenated gasoline is required to abate air pollution. Fumigants, which frequently are used for insect and nematode control in vineyards and orchards, were detected primarily in the Central Valley of California, an area with emphasis on this type of agriculture.

The half-life of a VOC, or the time it takes for one-half of the original concentration of the compound to degrade, is believed to be an important property that controls the occurrence of VOCs in ground water. With the exception of VOCs used in organic synthesis, the detection frequencies of VOCs were proportional to the average ground water half-life of the compounds. This result supports the contention that half-life is an important factor in influencing the occurrence of VOCs in ground water.

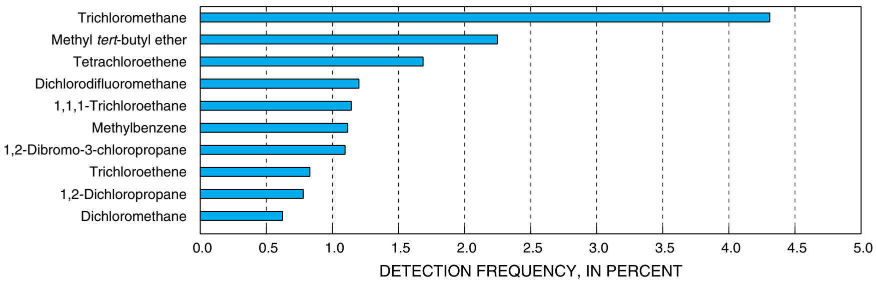

Figure 2. Top ten most frequently detected volatile organic compounds.

Sources of VOCs to Private Wells

The most common sources of VOCs to private wells likely are point sources such as underground storage tanks (USTs), septic systems, fertilizer applications, gasoline and chemical spills, pesticide applications, aboveground storage tanks (ASTs), pipelines, and sewer lines. Some rural homes use USTs and/or ASTs for storing gasoline, diesel fuel, or heating oil for domestic or agricultural purposes. Leakage from these tank systems, especially USTs, has the potential to be a significant source of ground water contamination to private wells. Leaks from UST systems usually are the result of faulty installation and corrosion of tanks and pipelines (U.S. Environmental Protection Agency 2000b).

Septic systems, which are common in rural areas, also have the potential to be important sources of ground water contamination to private wells. VOCs are common components of many household products and have been found frequently in septage and septic tank effluent. In fact, seven of the VOCs most frequently detected in this study have been found in a variety of household products that might be disposed in septic systems. Ground water contamination from septic systems can arise from a variety of construction and maintenance problems such as leaking tanks, poorly or improperly constructed tanks or leachfields, inadequate depth to water table, or highly permeable soils in the area of the leachfield. Improperly designed, maintained, or operated septic systems can result in ground water contamination in the vicinity of a private well if the well is hydraulically connected to shallow ground water near the leaking or faulty septic system.

Shock chlorination might be responsible for detections of chloroform in private wells. In this process, household bleach is added directly to the well to kill bacteria. The addition of bleach to ground water results in the formation of chloroform and similar compounds called trihalomethanes.

Human Health and VOCs in Private Wells

Although a relatively large number of people rely on private wells for water, the water from these wells is not scrutinized as closely, from a health standpoint, as water from public suppliers. The U.S. Environmental Protection Agency (U.S. EPA) has established maximum concentration standards or health criteria in drinking water for 42 of the 55 analyzed VOCs because of human health concerns such as carcinogenicity (U.S. Environmental Protection Agency 2000a). However, these federal standards and most state drinking water standards apply only to community water systems and certain noncommunity water systems serving a minimum number of people. Other concentration criteria also have been established or proposed for some VOCs to address concerns of drinking water such as taste, odor, and color. These other guidelines include a drinking water advisory for MTBE of 20 to 40 micrograms per liter (μg/L) and taste and odor thresholds for 32 other VOCs.

In this study, 27 wells, or 1.4 percent, had at least one VOC that exceeded either a U.S. EPA drinking water standard or other health criterion or both. The fumigant DBCP accounted for 57 percent of VOC concentrations that exceeded a drinking water standard; however, the maximum contaminant level (MCL) for DBCP is 0.2 μg/L, which is quite low relative to the MCLs for other VOCs. Most of the DBCP concentrations that exceeded the MCL occurred in the Central Valley of California where DBCP was used extensively on vineyards and orchards before its ban in 1985. Five other VOCs had one or more concentrations that exceeded drinking water standards or health criteria: 1,2-dibromoethane (EDB), trichloroethene (TCE), PCE, 1,2-dichloropropane, and 1,1-dichloroethene (Table 1). Two VOCs—the gasoline oxygenate MTBE and the fumigant 1,2-dichloropropane—had one or more concentrations

water quality/ *continues on page 34*

Table 1
Concentrations of VOCs in private wells that exceeded a drinking water standard, health criterion, or taste and odor threshold

Compound	Drinking water standard, health criterion, drinking water advisory or taste and odor threshold (µg/L)	Number of exceedances	Highest concentration measured in samples (µg/L)
DBCP	0.2	16	3.2
1,2-dibromoethane (EDB)	0.05	3	1.1
trichloroethene (TCE)	5	3	25
tetrachloroethene (PCE)	5	3	29
1,2-dichloropropane	5	2	19
1,1-dichloroethene	7	1	39
MTBE	20[1]	1	30

[1] Lower limit of U.S. EPA's drinking water advisory

water quality/*from page 33*

that exceeded a drinking water advisory or taste and odor threshold (Table 1).

Although concentrations of most VOCs detected in most private wells did not exceed drinking water standards or other health criteria, 13 of the 55 analyzed VOCs do not have drinking water standards or health criteria. In addition, the effects of low concentrations of some VOCs and the effects of mixtures of VOCs are not fully understood. Twenty-eight percent of private wells with detections of VOCs had two or more VOCs. Low-level concentrations of VOCs or mixtures of VOCs may be associated with significant adverse human health concerns (Ashford and Miller 1991). Thus, our understanding of the human health effects of VOCs in drinking water from private wells is incomplete.

Approximately 40 million people (about 15 percent of the United States population) received their household water from private wells in 2002, and the number is increasing. From 1970 to 1990, the number of households using private wells for water supply increased from 11 million to 15 million (Job 2002).

Information Still Needed

Although the NAWQA Program collected or compiled a large amount of data, there are many areas of the country where little information is known on VOCs in private wells. The areas where NAWQA information is lacking should be targeted for future sampling. In addition, other chemicals, such as nutrients, pesticides, and trace elements, could be present in private wells. Samples of ground water from private wells should be analyzed for a broad suite of chemicals in order to provide a complete understanding of water quality, including the types of mixtures of contaminants that occur. Determining the mixtures of contaminants that occur in private wells is important so that toxicologists can evaluate the potential health effects of such mixtures. In addition, NAWQA has not yet analyzed for microbial contaminants in private wells, and the presence of these contaminants can have substantial potential health effects. Monitoring of private wells for microbial contaminants should be conducted at a large scale in order to characterize the occurrence of these contaminants.

It also is important to understand the sources and transport of contaminants like VOCs to private wells. Identifying sources and transport mechanisms will help in developing strategies to reduce the risk of contamination. Although some potential sources of contaminants and transport pathways can be identified, additional research will help determine the natural and anthropogenic factors associated with contamination. As an example, research could help to identify the relative importance of leaking USTs and septic systems in contamination of private wells and the effect of hydrogeology. Another important area that requires investigation is the relation between shock chlorination and the formation of chloroform in private wells. Research of the sources and transport of VOCs to private wells can be facilitated by the proper and complete documentation of well construction and hydrogeologic characteristics of each well at the time the well is installed.

Continued monitoring of private wells for natural and anthropogenic chemicals is important because these wells are a source of drinking water for a large number of people in the United States. Because owners of private wells are not required to monitor for contaminants of concern or contaminants with health standards or guidelines, they may not be aware of contamination in their drinking water. Continued monitoring and research into the quality of water from private wells will also bring more attention to the issues involved with rural water quality.

References

Ashford, N.A., and C.S. Miller. 1991. *Chemical Exposures—Low Levels and High Stakes*. New York: Van Nostrand Reinhold.

Job, C. 2002. Protecting household wells. *Ground Water Monitoring & Remediation* 22, no. 2: 43-44.

Moran, M.J., W.W. Lapham, B.L. Rowe, and J.S. Zogorski. 2002. Occurrence and status of volatile organic compounds in ground water from rural, untreated, self-supplied domestic wells in the United States, 1986-99. U.S. Geological Survey Water-Resources Investigations Report 02-4085.

U.S. Environmental Protection Agency. 2000a. Drinking water standards and health advisories. Washington, D.C.: Office of Water, USEPA 822-B-00-001.

U.S. Environmental Protection Agency. 2000b. National water quality inventory, 1998 Report to Congress. Washington, D.C.: USEPA 841-R-00-001.

This article is based on technical findings presented in USGS Water-Resources Investigations Report 02-4085, "Occurrence and Status of Volatile Organic Compounds in Ground Water from Rural, Untreated, Self-Supplied Domestic Wells in the United States, 1986-99." This report can be purchased from USGS Information Services, Box 25286 Federal Center, Denver, CO 80225 or fax request to (303) 202-4693. The report also can be obtained online at *http://sd.water.usgs.gov/nawqa/vocns*. Questions regarding the report should be directed to Michael Moran at (605) 355-4560, ext. 244, or *mjmoran@usgs.gov*. *WWJ*

Michael Moran is a hydrologist for the U.S. Geological Survey. Currently he works on analyzing and interpreting ground water quality data for the National Water-Quality Assessment (NAWQA) Program. His work includes analyzing and interpreting data on VOCs in ground water, designing national-scale ambient ground water monitoring programs and networks, and developing statistical models to predict the probability of occurrence of VOCs in ground water.

Pixie Hamilton is a hydrologist for the U.S. Geological Survey. She currently serves as a Staff Hydrologist and Water Information Coordinator for the National Water-Quality Assessment (NAWQA) Program. Her work involves regional ground water modeling, regional and national water-quality assessments, and communicating research and technical implications of NAWQA information to government, research, and interest-group partners.