NATIONAL WATER-QUALITY ASSESSMENT PROGRAM

Quality of Shallow Ground Water in Areas of Recent Residential and Commercial Development in Salt Lake Valley, Utah, 1999

Significant Findings

- The nitrate concentration in water sampled from 26 of the 30 monitoring wells was higher than an assumed background level of 3 mg/L.
- At least one of the herbicides, atrazine, prometon, simazine, or tebuthiuron was detected in water sampled from 25 of the 30 monitoring wells.
- Chloroform, most likely from chlorinated public-supply water that has recharged the shallow aquifer, was detected in water sampled from 27 of the 30 monitoring wells.
- Tetrachloroethene was detected in water sampled from 16 of the 30 monitoring wells with 1 concentration greater than the U.S. Environmental Protection Agency 5 µg/L maximum contaminant level for drinking water.

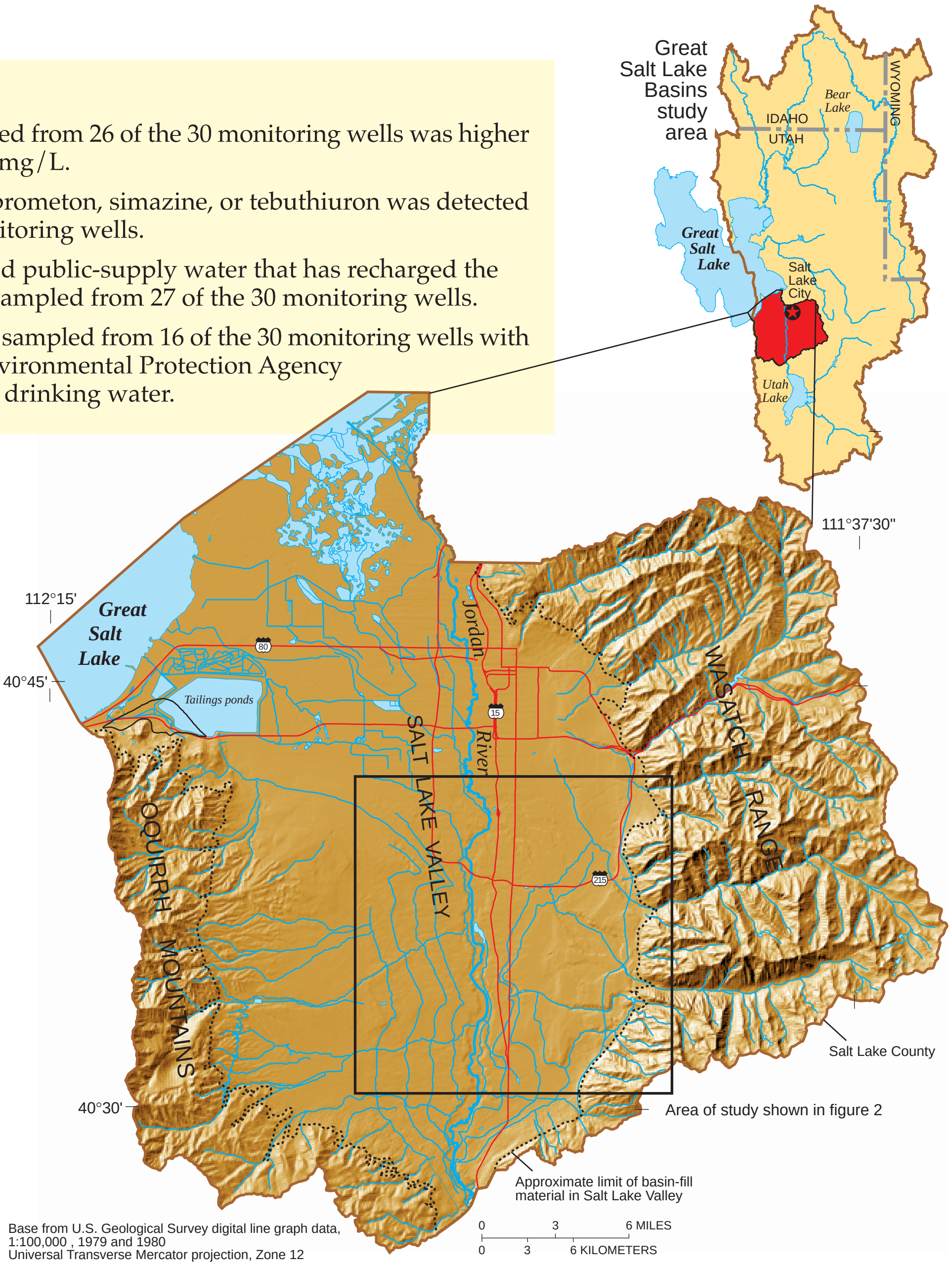

Figure 1. Location of residential/commercial land-use study area in Salt Lake Valley, Utah.

Introduction

Residential and commercial development of about 80 square miles that primarily replaced undeveloped and agricultural areas occurred in Salt Lake Valley, Utah, from 1963 to 1994. The effects of human activities on the quality of shallow ground water in the recently developed areas were studied by the U.S. Geological Survey (USGS) as part of the National Water-Quality Assessment (NAWQA) program. The land-use study consisted of 30 monitoring wells installed and sampled in 1999 in residential/commercial areas where shallow ground water has the potential to move to a deeper public-supply aquifer. The water samples were analyzed for major ions, nutrients, pesticides, volatile organic compounds (VOCs), trace elements, and radon. The occurrence of nitrate, pesticides, and VOCs in water sampled from these wells can serve as an indicator of water affected by human activities at land surface. This report describes the nitrate, pesticide, and VOC data collected during the study.

Description of Study Area

Salt Lake Valley covers almost 500 square miles and contains the Salt Lake City metropolitan area (fig. 1). It is bound on the east by the Wasatch Range and on the west by the Oquirrh Mountains. Mountain streams discharge into the Jordan River, which flows north along the axis of the valley and discharges into Great Salt Lake. The climate in Salt Lake Valley is semiarid, with a normal precipitation rate of about 12 to 20 inches per year. Lawns and gardens in the valley require irrigation to supplement precipitation during the growing season.

The population in Salt Lake County in 1999 was about 850,000 (U.S. Census Bureau, written commun., 2000) and is growing rapidly. The population almost doubled between 1963 and 1994, corresponding to areas with recent residential and commercial development in the valley (fig. 2). The cities of Sandy and West

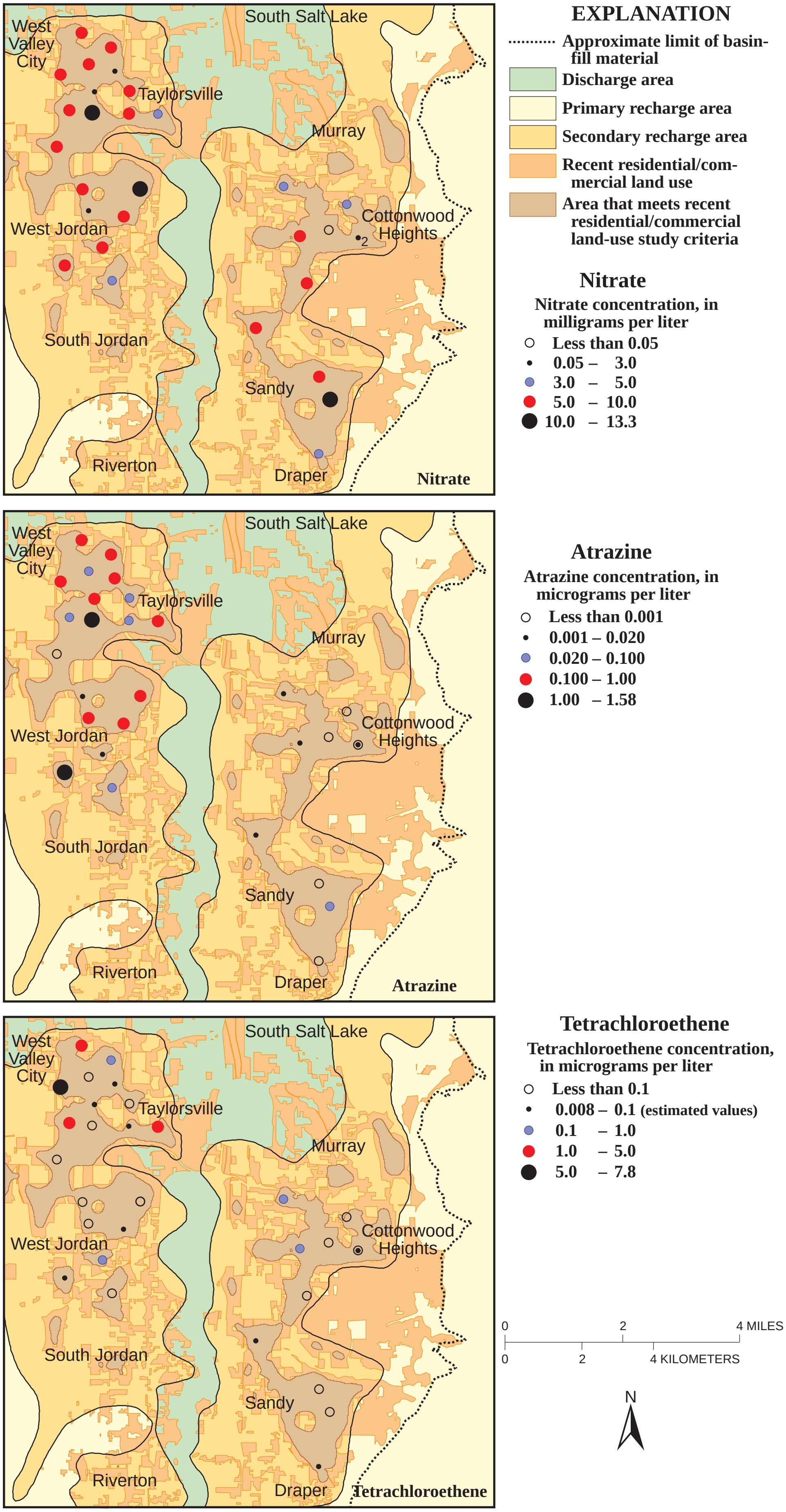

Figure 2. Distribution of nitrate, atrazine, and tetrachloroethene concentration in water sampled from monitoring wells in Salt Lake Valley, Utah.

Jordan have experienced substantial growth. An adequate supply of water that is suitable for domestic use is one of the most important factors in sustaining the current population and in allowing for continued economic growth in Salt Lake Valley.

Ground Water in Salt Lake Valley

A generalized model of the saturated basin-fill material in Salt Lake Valley consists of a relatively deep unconfined aquifer near the mountain fronts that becomes confined toward the center of the valley by interbedded, discontinuous layers of silt and clay (fig. 3). Overlying this confined aquifer is a shallow, generally unconfined aquifer. The primary recharge area for the deeper aquifers is near the mountain fronts where there are no substantial layers of fine-grained material to impede movement of water. Downward leakage of water from the shallow aquifer to the deeper confined aquifer is possible where a downward gradient exists and confining layers are thin, absent, or discontinuous. These conditions can exist in the secondary recharge area.

The shallow, generally unconfined aquifer is susceptible to contamination from activities related to land use because of its proximity to land surface. Water from this aquifer is not currently used for drinking. The deeper unconfined aquifer also is vulnerable because of a lack of confining layers that can impede the downward movement of contaminated ground water. Water quality in the deeper confined aquifer can be degraded by the secondary recharge of contaminated water from the shallow and deeper unconfined aquifers. The deeper unconfined and confined aquifers in Salt Lake Valley are used extensively for public supply. More than half of the population in the valley receives ground water for household use.

Volatile organic compounds have been recently detected in water pumped from public-supply wells completed in deeper aquifers. These wells are primarily in urban/residential areas within the valley (Thiros, 2000). Tetrachloroethene was detected in water from seven public-supply wells in Salt Lake and Davis Counties. Contamination of drinking-water supplies from VOCs and pesticides is a human health concern because many are toxic and are known or suspected human carcinogens (U.S. Environmental Protection Agency, 1996). These compounds are difficult and expensive to remove from ground water. Additional data and interpretation are needed to determine the occurrence, distribution, and sources of VOCs in the shallow aquifer and the deeper drinking-water supply aquifers in Salt Lake Valley.

Site Selection and Well Installation

Study sites were selected with a computerized, stratified random selection process (Scott, 1990). It identified 41 sites in Salt Lake Valley that met the study criteria: (1) location in residential and commercial areas developed from 1963 to 1994; (2) 75 percent of a 500- meter circular buffer around the site contains targeted land use; (3) a downward gradient exists between the shallow and deeper aquifers; and (4) a minimum distance of 1 kilometer exists between each site (Squillace and Price, 1996). Areas developed after 1994 were not included in this study because of the time necessary for new construction to affect the ground-water system. Areas developed before 1963, such as downtown Salt Lake City, were also excluded because of a greater potential for the land use to have changed with time.

Monitoring wells were installed at 30 of the 41 sites according to NAWQA protocols (Lapham and others, 1995) (fig. 2). Depth of monitoring wells ranged from 23 to 153 feet, and the wells were completed with a 10-foot length of screen. The top of the screened interval generally was about 5 feet below the water table. One site was completed with two wells to determine water-quality variations with depth in the shallow aquifer. The water level at another site dropped below the bottom of the well and no water sample was collected. Water levels in the wells ranged from about 5 to 135 feet below land surface.

Protocols for parts-per-billion-level ground-water sampling documented by Koterba and others (1995) were followed in the collection and processing of the samples. The USGS National Water Quality Laboratory analyzed the samples. A quality-control program was used in the field (Koterba and others, 1995) and in the laboratory to evaluate and ensure the reliability of the data.

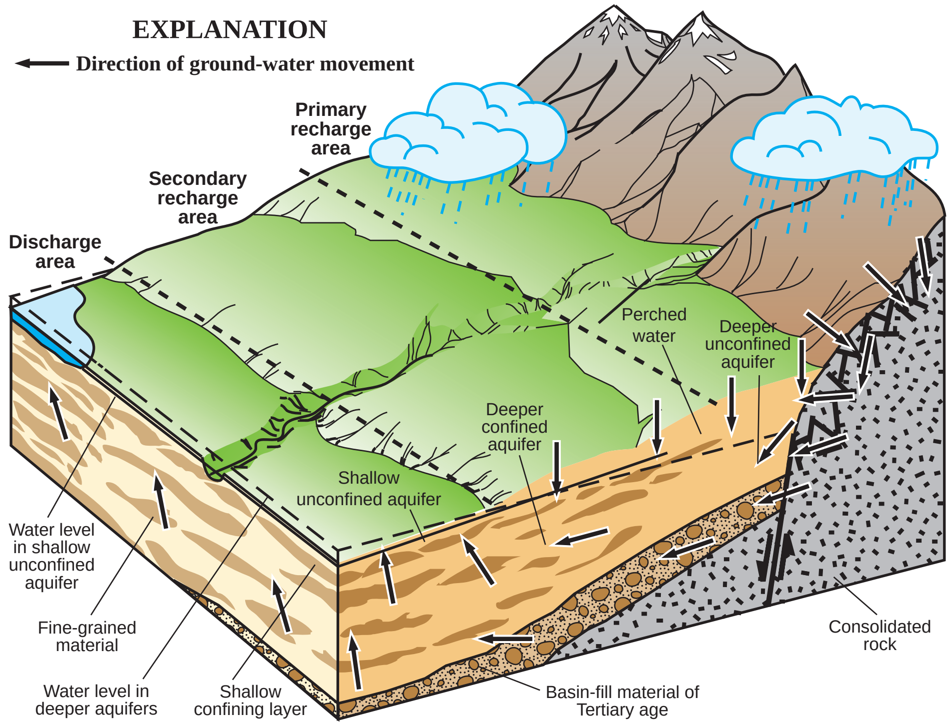

Figure 3. Generalized block diagram showing the basin-fill ground-water flow system, Great Salt Lake Basins Study unit. (Modified from Hely and others, 1971.)

Chemicals Detected in Shallow Ground Water

Nitrate

Although nitrate as nitrogen can occur naturally in ground water, elevated concentrations in urban areas are typically caused by human activities. Some of the potential sources of nitrate in ground water include nitrate leaching from areas where manure has been applied, leaking or improperly functioning septic systems and sewer pipes, and nitrogen-based fertilizers applied to lawns and gardens. Background nitrate concentrations in ground water from areas not associated with agricultural practices commonly are less than 2 to 3 milligrams per liter (mg/L) as nitrogen (Halberg and Keeney, 1993, p. 316). Some existing nitrate data for ground water in the Great Salt Lake Basins study area are available from the USGS National Water Information System database. The median nitrate concentration in water located in urban/residential areas sampled from wells less than 150 feet deep was 1.1 mg/L (71 analyses); in water sampled from wells greater than 150 feet deep, generally completed in the deeper unconfined aquifers, it was less than 1 mg/L (110 analyses).

Nitrate concentration in water sampled from 26 of the 30 monitoring wells (86.7 percent) was higher than an assumed background level of 3 mg/L, indicating a possible human influence. Concentrations ranged from less than 0.05 mg/L to 13.3 mg/L (fig. 2). The median nitrate concentration for the 30 samples was 6.8 mg/L.

The U.S. Environmental Protection Agency's (EPA) maximum contaminant level (MCL) for nitrate in drinking water (10 mg/L) was exceeded in water from 3 of the 30 wells (10 percent). Water from 19 wells had concentrations greater than 5 mg/L (63.3 percent). High nitrate concentrations can cause methemoglobinemia or "blue-baby syndrome" in small children and results from the reduced oxygen-carrying capacity of blood after the body converts nitrate to nitrite.

Pesticides

Nationally, pesticide results are available from 41 NAWQA land-use studies completed during 1993–95. Pesticide compounds in shallow ground water were commonly detected nationally in both agricultural (56.4 percent; 813 sites) and urban (46.6 percent; 221 sites) settings (Kolpin and others, 1998). The most frequently detected pesticides in shallow ground water in urban areas were prometon, atrazine, deethylatrazine (DEA), simazine, and tebuthiuron, all herbicides. These were also the most frequently detected pesticides in the Salt Lake Valley study (table 1) with at least 1 compound detected in water sampled from 25 of the 30 monitoring wells. Prometon, atrazine, simazine, and tebuthiuron are used to control weeds and other vegetation primarily along roads, driveways, rights-of-way, parking lots, and utility corridors, and all, except for prometon, may only be used by licensed applicators. Nationally, insecticides were seldom detected in ground water in urban areas.

The water samples were analyzed for 86 pesticides by using capillary column gas chromatography/mass spectrometry (Zaugg and others, 1995). The minimum reporting level (MRL) for each compound indicates relative analytical precision and detection sensitivity, but some concentrations were reported in concentrations below the MRL if the identification criteria for the method were met. Concentration values for detections below MRLs are designated as estimated values. Overall, the MRL for pesticides analyzed for the NAWQA program are lower than those of analyses done for regulatory purposes.

The most frequently detected pesticides in water sampled for the study were atrazine (76.7 percent), prometon (50 percent), simazine (43 percent) and tebuthiuron (13.3 percent). At a common detection threshold of 0.10 micrograms per liter (μg/L), the most frequently detected pesticides were atrazine (36.7 percent) and prometon (20 percent). All of the pesticide concentrations measured were less than MCLs or health advisories for drinking water (table 1). Water samples from two monitoring wells had concentrations greater than 1 μg/L of atrazine but less than the MCL of 3 μg/L (fig. 2). The water level in one of these wells is greater than 130 feet below land surface. The presence of pesticides in shallow ground water from residential/commercial areas indicates relatively fast movement from the land surface to the shallow aquifer and is of concern because of the potential for movement to the underlying drinking-water-supply aquifer.

Atrazine was detected in water sampled from 23 wells (table 1). All of the

Table 1. Summary of pesticides and volatile organic compounds detected in water sampled from 30 residential/commercial area monitoring wells in Salt Lake Valley, Utah, 1999

[Units in micrograms per liter; Maximum Contaminant Level is the U.S. Environmental Protection Agency established drinking water standard (U.S. Environmental Protection Agency, 1996); Lifetime Health Advisory is defined as the concentration of a chemical in drinking water that is not expected to cause any adverse noncarcinogenic effect over a lifetime of exposure within a specified margin of safety (U.S. Environmental Protection Agency, 1996); -, no applicable standard; E, estimated value]

Pesticide	Trade name(s) or abbreviation	Predominant use	Number of detections	Maximum concentration	Minimum reporting level	Maximum Contaminant Level	Lifetime Health Advisory
Atrazine	AAtrex	restricted use herbicide	23	1.58	0.001	3	3
Deethylatrazine	DEA, Desethylatrazine	degradation product of atrazine	22	.320 E	.002	-	-
Prometon	Pramitol	general use herbicide	15	.518	.018	-	100
Simazine	Aquazine, Princep	restricted use herbicide	13	.027	.005	4	4
Tebuthiuron	Brush, Spike, Perflan	restricted use herbicide	4	.120	.010	-	500
Diazinon	D-Z-N	restricted use insectide	1	.002 E	.002	-	.6
Malathion	Cythion	general use insectide	1	.006	.005	-	200
P,P' DDE	DDE	degradation product of DDT	1	.002 E	.006	-	.1
Volatile organic compound	**Alternative name or abbreviation**	**Predominant use**	**Number of detections**	**Maximum concentration**	**Minimum reporting level**	**Maximum Contaminant Level**	**Lifetime Health Advisory**
Chloroform	Trichloromethane	solvent, chlorination byproduct	27	2.41	0.052	100	-
Bromodichloromethane	Dichlorobromomethane	chlorination byproduct	17	.508	.048	100	-
Tetrachloroethene	Tetrachloroethylene, PCE	solvent	16	7.85	.100	5	-
1,1,1-Trichloroethane	Methyl chloroform, TCA	solvent	15	.224	.032	200	200
Dichloromethane	Methylene chloride	solvent	6	.319 E	.380	5	-
Trichloroethene	Trichloroethylene, TCE	solvent	5	1.54	.038	5	-
m+p Xylene	1,3 + 1,4-Dimethylbenzene	gasoline aromatic hydrocarbon	4	.081 E	.060	10,000	10,000
Carbon disulfide	-	naturally occurring, organic synthesis	3	.096 E	.370	-	-
Benzene	-	gasoline aromatic hydrocarbon	2	.006 E	.100	5	-
Ethylbenzene	Ethylbenzol	gasoline aromatic hydrocarbon	2	.018 E	.030	700	700
Toluene	Methylbenzene	gasoline aromatic hydrocarbon	2	.010 E	.050	1,000	1,000
Trichlorofluoromethane	Freon 11, CFC 11	refrigerant, aerosol propellant	2	.087 E	.090	-	2,000
1,1-Dichloroethene	1,1-DCE	organic synthesis	2	.045 E	.044	7	7
1,2,4-Trimethylbenzene	Psuedocumene	organic synthesis	2	.032 E	.056	-	-
Methyl tert-butyl ether	MTBE	fuel oxygenate	1	.123 E	.170	-	20-40

Area surrounding a residential/commercial land-use study monitoring well in Salt Lake Valley.

wells with atrazine concentrations greater than 0.1 μg/L are located on the west side of Salt Lake Valley (fig. 2). This may be the result of a particular land use, aquifer properties such as recharge rate or transmissivity, or a combination of factors. Deethylatrazine is a degradation product of atrazine and was detected in all but one of the samples that contained atrazine.

Prometon was detected in water sampled from 15 wells (table 1) and in 6 of the 11 samples collected from wells on the east side of the valley. The maximum concentration of 0.518 μg/L is much less than the health advisory for drinking water of 100 μg/L. Prometon is registered for use by homeowners to control vegetation. Nationally, it was the most frequently detected herbicide in ground water at urban sites sampled during 1993–95 for the NAWQA program (Kolpin and others, 1998).

Simazine was detected in water sampled from 13 wells with a maximum concentration of 0.027 μg/L (table 1). Of the 13 detections, 12 were from samples in the northwestern part of the area and 1 from the eastern part.

Volatile Organic Compounds

Volatile organic compounds are carbon-containing chemicals that readily evaporate at normal air temperature and pressure. They are contained in many manufactured products such as gasoline, paints, adhesives, solvents, wood preservatives, dry-cleaning agents, pesticides, fertilizers, cosmetics, and refrigerants. Potential sources of VOCs to ground water are direct industrial and wastewater discharges, infiltration of accidental spills, leaking underground storage tanks, stormwater runoff, and atmospheric deposition of vehicle and industrial emissions. The U.S. Environmental Protection Agency (1996) has established MCLs in drinking water for 27 VOCs because of human health concerns.

NAWQA urban land-use studies collected about 300 shallow ground water VOC samples during 1993–95 from study units located across the country (Volatile Organic Compound National Synthesis Project, U.S. Geological Survey, written commun., 1998). Nationally, the most frequently detected VOCs were chloroform, methyl tert-butyl ether (MTBE, an additive to gasoline), tetrachloroethene, and trichloroethene. At a national scale, these compounds were generally detected at low concentrations that were almost always below MCLs or health advisories for drinking water.

Detection of many VOCs is the result of improved analytical methods that allow measurement of lower concentrations (Conner and others, 1998). The most frequently detected VOCs in water sampled for the study were chloroform (90 percent), bromodichloromethane (56.7 percent), tetrachloroethene (53.3 percent), and 1,1,1-trichloroethane (50 percent) (table 1). At a common detection threshold of 0.10 μg/L, the most frequently detected VOCs were chloroform (70 percent), bromodichloromethane (30 percent), tetrachloroethene (26.7 percent), and 1,1,1-trichloroethane (10 percent).

The widespread occurrence of chloroform and bromodichloromethane in shallow ground water is likely a result of disinfected public-supply water used to irrigate lawns and gardens in residential areas of Salt Lake Valley. Chloroform and bromodichloromethane are byproducts of chlorinated ground and surface water reacting with organic material.

Tetrachloroethene (perchloroethylene, PCE), primarily used as a dry cleaning agent and solvent, was detected in water sampled from 16 wells (table 1). Although the median concentration of PCE for samples was less than the minimum reporting level of 0.10 μg/L, water from four wells had concentrations greater than 1 μg/L. These wells are all in the northwestern part of the study area (fig. 2). The maximum PCE concentration measured was 7.85 μg/L, greater than the MCL in drinking water of 5 μg/L. It is not known if the PCE detected in the ground water in this area is from a point source or is part of a larger, diffuse plume.

Trichloroethene (TCE) and 1,1,1-trichloroethane (TCA) are commonly used as solvents (table 1). Trichloroethene was detected in water sampled from five wells; the maximum concentration was 1.54 μg/L. 1,1,1-tricloroethane was detected in water sampled from 15 wells; the maximum concentration was 0.22 μg/L. The widespread occurrence of VOCs generally used as solvents in the shallow unconfined aquifer in mostly residential areas may be the result of their presence in household products used for cleaning, painting, car care, and other uses.

Methyl tert-butyl ether (MTBE) was detected near the minimum reporting level in water from one well (table 1). This compound is used to oxygenate gasoline to improve combustion and reduce air-quality degradation. Ethanol is the primary oxygenate used in gasoline in the area but MTBE is used as an octane booster. Because of the high solubility of MTBE

Photo credit: Susan Thiros © 2000

Drill rig installing a monitoring well in a residential area.

Photo credit: Susan Thiros © 2000

Golf course and residential development on west side of Salt Lake Valley, with Wasatch Range in background.

in water, atmospheric washout in urban areas may be the source of low concentrations in ground water (Squillace and others, 1996).

Implications

The presence of nitrate, pesticides, and volatile organic compounds in shallow ground water indicates relatively rapid movement of water from land surface and therefore, vulnerability to contamination from these and other compounds. The deeper confined aquifer used for public supply in Salt Lake Valley may also be vulnerable because the potential exists for water to move downward from the shallow aquifer. More information is needed on the movement of ground water and on the occurrence and distribution of pesticides and volatile organic compounds in the deeper drinking-water supply aquifers.

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The USGS thanks the landowners, and officials of municipalities, and Salt Lake County who allowed USGS personnel access to their properties for the purpose of installing and sampling monitoring wells.

National Water-Quality Assessment Program

The Great Salt Lake Basins study unit is 1 of 50 study units involved in the USGS NAWQA program. The goals of the NAWQA program are to describe the status and trends in the quality of the Nation' s ground- and surface-water resources and to gain a better understanding of the natural and human factors that affect the quality of these resources. The study design balances the unique assessment requirements of individual hydrologic systems with a nationally consistent design structure that incorporates a multi-scale, interdisciplinary approach.

Information on the NAWQA Program can be obtained from:

Great Salt Lake Basins NAWQA Chief
U.S. Geological Survey
2329 Orton Circle
Salt Lake City, UT 84119-2047

http://ut.water.usgs.gov

Additional information on health effects of nitrate, pesticides, or VOCs in drinking water and drinking-water regulations can be obtained by calling the EPA Safe Drinking Water Hotline at 1–800–426–4791.

— By S.A. Thiros

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