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Scientific Investigations Map 2931

The Occurrence of Volatile Organic Compounds in Aquifers of the United States

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Study basics

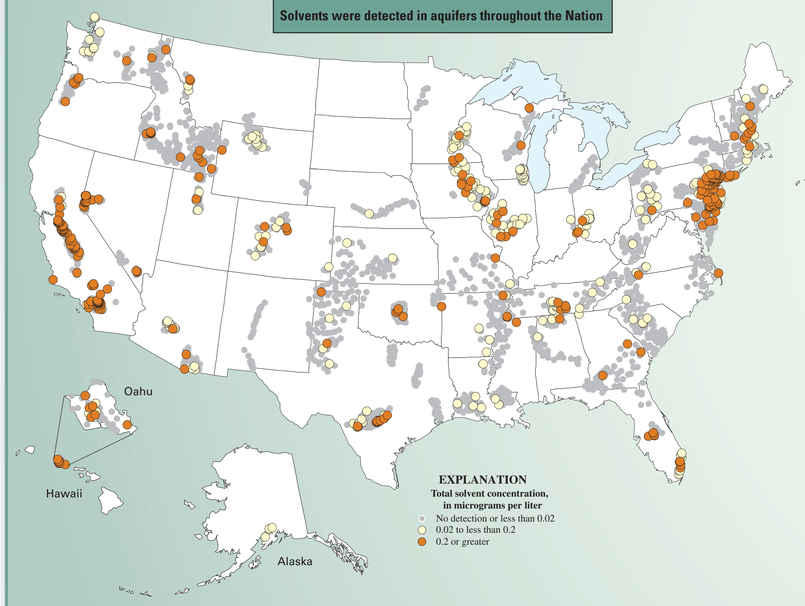
The U.S. Geological Survey's National Water-Quality Assessment (NAWQA) Program recently completed a national assessment of volatile organic compounds (VOCs) in ground water (Zogorski and others, 2006). As part of this assessment, samples of ambient ground water collected from 3,498 wells during 1985–2002 were selected for characterizing the occurrence of 55 VOCs in 98 aquifer studies. The 55 VOCs were assigned to the following groups on the basis of their primary usage (or origin): (1) fumigants, (2) gasoline hydrocarbons, (3) gasoline oxygenates, (4) organic synthesis compounds, (5) refrigerants, (6) solvents, and (7) trihalomethanes (chlorination by-products).

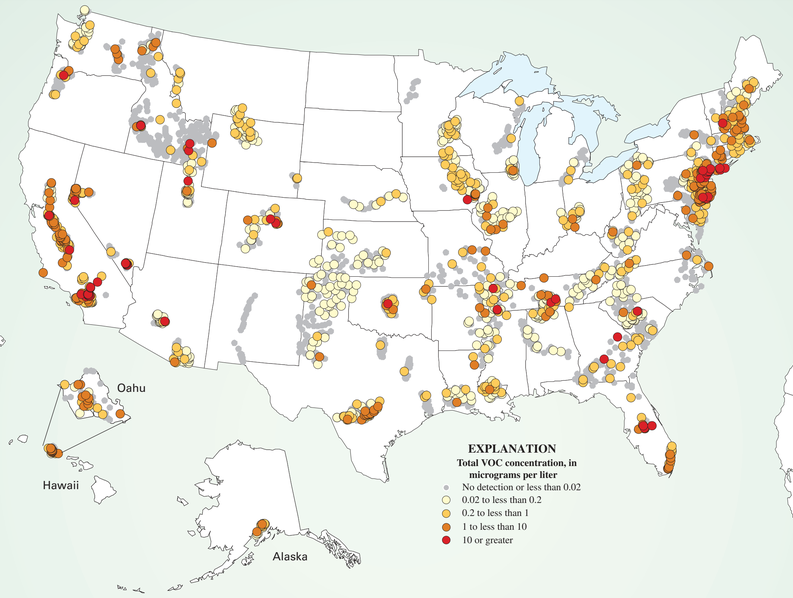
The samples were collected throughout the conterminous United States as well as Alaska and Hawaii. The sampled wells had a variety of uses including domestic supply (61 percent), public supply (15 percent), monitoring (10 percent), other (13 percent), and unknown (1 percent).

NAWQA aquifer studies are large-scale resource assessments of ground water that provide a general characterization of water-quality conditions in locally and regionally important aquifers or portions thereof. In general, the aquifers (or portions thereof) selected for study were some of the most intensively used aquifers for drinking water in the Nation. The 98 aquifer studies collectively provide an important national perspective on the current (1985–2002) extent of VOC contamination and regional patterns of VOC occurrence in ground water. More information about this national assessment of VOCs is available at a supporting Web site (http://water.usgs.gov/nawqa/vocs/national_assessment).

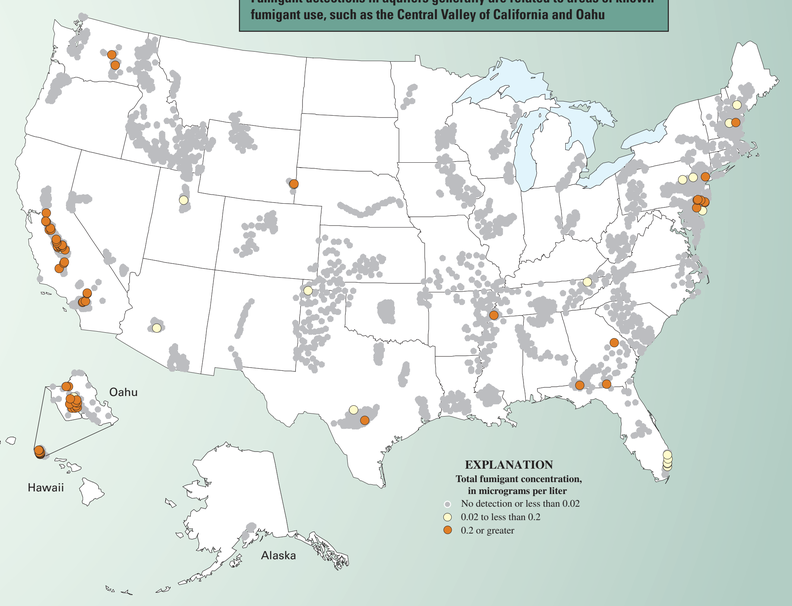
Occurrence

Solvents were detected in aquifers throughout the Nation



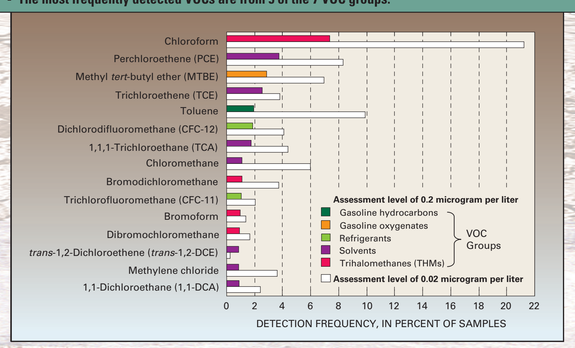


Fumigant detections in aquifers generally are related to areas of known fumigant use, such as the Central Valley of California and Oahu

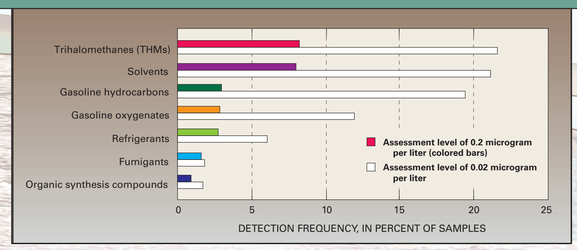


- Although infrequent, total VOC concentrations of 10 micrograms per liter or greater per sample were found in many States throughout the Nation.
- VOC contamination occurs in aquifers across the Nation, albeit over a large range of concentrations.

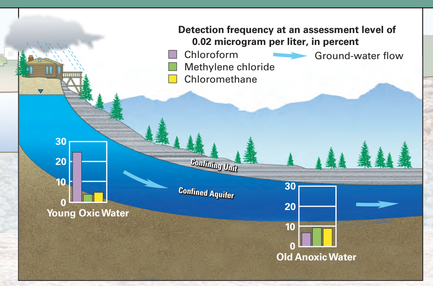
- Forty–two of the 55 VOCs were detected in aquifers at an assessment level of 0.2 microgram per liter.
- The 15 most frequently detected VOCs in aquifers are shown below.
  - Chloroform was the most frequently detected compound.
  - Methyl *tert*-butyl ether (MTBE) was one of the most frequently detected VOCs despite the short period of its extensive use.
  - The most frequently detected VOCs are from 5 of the 7 VOC groups.



- Trihalomethanes (THMs) and solvents were the most frequently detected groups of VOCs in aquifers.
- The detection frequencies in aquifers vary between VOC groups.



- The detection frequencies of most VOCs were dependent on the dissolved-oxygen conditions of ground water and the type of VOC.
- For example chloroform in young oxic ground water will tend to biodegrade to form methylene chloride and chloromethane in old anoxic ground water.



- Of the 55 VOCs included in the national assessment, 13 VOCs (shown below) were not detected in aquifer samples at a concentration of 0.2 microgram per liter or larger.
- At least one VOC in 5 of the 7 VOC groups was not detected.

Compound name	VOC group
Acrolein	Organic synthesis compound
Acrylonitrile	Organic synthesis compound
Hexachlorobutadiene	Organic synthesis compound
1,2,3-Trichlorobenzene	Organic synthesis compound
Vinyl bromide	Organic synthesis compound
1,3-Dichlorobenzene	Solvent
Hexachloroethane	Solvent
1,2,4-Trichlorobenzene	Solvent
1,1,2-Trichloroethane	Solvent
cis-Dichloropropene	Fumigant
trans-Dichloropropene	Fumigant
Styrene	Gasoline hydrocarbon
Ethyl *tert*-butyl ether	Gasoline oxygenate

- Ten frequently detected VOCs were statistically associated with factors that relate to their sources, transport, and fate in ground water.
- The source, transport, and fate properties shown below were associated with the occurrence of one or more of the 10 frequently detected VOCs shown on the left.
- The concentration of dissolved oxygen was the most common explanatory factor.

Compounds included in analysis

Compound name	VOC group
1,2,4-Trimethylbenzene	Gasoline hydrocarbon
Toluene	Gasoline hydrocarbon
Methyl *tert*-butyl ether	Gasoline oxygenate
Chloromethane	Solvent
Methylene chloride	Solvent
1,1,1-Trichloroethane	Solvent
Trichloroethene	Solvent
Perchloroethene	Solvent
Bromodichloromethane	Trihalomethane
Chloroform	Trihalomethane

Factors most commonly associated with VOCs in aquifers

Source factors
- Septic systems
- Urban land
- Resource Conservation and Recovery Act (RCRA) hazardous-waste facilities
- Gasoline storage and release sites

Transport factors
- Climatic conditions
- Hydric (anoxic) soils
- Depth to top of well screen

Fate factor
- Dissolved oxygen in ground water

Indeterminate factor
- Type of well

Implications

- Many of the Nation's aquifers are vulnerable to low-level VOC contamination, indicating the need to include VOCs in ground-water monitoring programs to track the trend of the low-level VOC contamination identified in this assessment.
- The natural and anthropogenic factors important to VOC occurrence in a particular aquifer need to be understood in order to effectively manage and protect aquifers that are susceptible to VOC contamination.
- A careful review of the importance and feasibility of further reducing or eliminating VOC sources to aquifers also is needed to manage and protect these aquifers.
- Some VOCs that are mobile and persistent (such as MTBE, perchloroethene, and chloroform) may reach especially susceptible aquifers within a decade or less of extensive use and potentially adversely affect ground-water quality.
- The environmental behavior and fate properties of anthropogenic compounds should be included in decision-making processes prior to their approval for large-scale commercial, industrial, and other uses.
- Some of the 55 VOCs included in this assessment may not warrant continued inclusion in large-scale resource assessments, such as aquifer studies completed in the NAWQA Program, if it is confirmed that their use, release, and behavior and fate characteristics pose a small or negligible likelihood of ground-water contamination.

Reference

Zogorski, J.S., Carter, J.M., Ivahnenko, Tamara, Lapham, W.W., Moran, M.J., Rowe, B.L., Squillace, P.J., and Toccalino, P.L., 2006, The quality of our Nation's waters—Volatile organic compounds in the Nation's ground water and drinking-water supply wells: U.S. Geological Survey Circular 1292, 101 p.