Groundwater Contaminant Science Activities of the U.S. Geological Survey in New England

Aquifers in New England provide water for human needs and natural ecosystems. In some areas, however, aquifers have been degraded by contaminants from geologic and human sources. In recent decades, the U.S. Geological Survey (USGS) has been a leader in describing contaminant occurrence in the bedrock and surficial aquifers of New England. In cooperation with Federal, State, and local agencies, the USGS has also studied the vulnerability of groundwater to contaminants, the factors affecting the geographic distribution of contaminants, and the geochemical processes controlling contaminant transport and fate. This fact sheet describes some of the major science needs in the region related to groundwater contaminants and highlights recent USGS studies that provide a foundation for future investigations.

Future Science Needs for Groundwater Contaminants

Improved understanding of groundwater contaminants is needed to protect water resources, natural ecosystems, and public health in New England. Specific topics requiring future study include the following:

- Occurrence, distribution, and mobilization of groundwater contaminants from geologic sources, including arsenic, lead, radon, and uranium
- Relations between human land use (agricultural, industrial, residential, transportation, and waste disposal) and contaminant concentrations in groundwater
- Development and application of new field, laboratory, and modeling methods for improved understanding of groundwater contaminants in New England
- Geographic distribution of human-health risk in relation to groundwater contaminant sources

Occurrence and Distribution of Contaminants From Geological Sources

Chemical reactions between groundwater and solid aquifer material can cause the dissolution or desorption of contaminants from an aquifer. Groundwater contaminants that result from such reactions include arsenic, lead, radon, and uranium. The distribution of arsenic in groundwater has been assessed throughout most of New England. By contrast, the distribution of other elements, such as dissolved uranium, is only beginning to be studied.

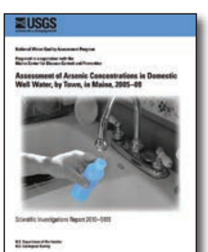
Estimated Probabilities of Arsenic Occurrence in Bedrock Aquifers of New Hampshire

Probabilities of arsenic occurrence at concentrations of 1, 5, and 10 micrograms per liter (µg/L) were estimated in 2011 using multivariate logistic regression. About 39 percent of groundwater in bedrock aquifers in New Hampshire was identified as having at least a 50-percent chance of containing an arsenic concentration greater than or equal to (≥) 1 µg/L; 7 percent had at least a 50-percent chance of a concentration ≥5 µg/L, and about 5 percent had at least a 50-percent chance of concentrations ≥10 µg/L. Important predictors of arsenic in groundwater from bedrock aquifers included geologic, geochemical, land use, hydrologic, topographic, and demographic factors. ***Publication at*** **http://pubs.er.usgs.gov/publication/sir20125156**.

Arsenic and Uranium in Private Bedrock Wells of East-Central Massachusetts

A total of 478 randomly selected wells were sampled by private-well users to evaluate arsenic and uranium concentrations in the bedrock aquifer of east-central Massachusetts. Results indicated that 13 percent of the wells contained water with concentrations greater than the drinking-water standard established for public wells for arsenic, and 3.5 percent had concentrations greater than the drinking-water standard for uranium. Arsenic and uranium did not in general occur together in water of a given well. A statistical model was used to show that about 5,700 and 3,300 wells in the study area are likely to contain concentrations of arsenic and uranium, respectively, that are above standards. ***Publication at*** **http://pubs.er.usgs.gov/publication/sir20115013**.

Arsenic in Private Domestic Wells in Maine



Data for arsenic concentrations in domestic wells from 2005 to 2009 were obtained from the Maine Health and Environmental Testing Laboratory (HETL) and assessed statistically by the USGS using procedures that assured the privacy of well owners. A total of 174 towns had samples from 20 or more wells. In 44 of these towns, more than 25 percent of the wells had arsenic concentrations greater than applicable drinking water standards (10 µg/L). In 19 towns, concentrations in more than 10 percent of the wells exceeded 50 µg/L, and in 45 towns, concentrations in 1 percent or more of the wells exceeded 100 µg/L. The distribution of high arsenic concentrations appeared to be associated with bedrock geology, as has been found elsewhere in New England. ***Publication at*** **http://pubs.usgs.gov/sir/2010/5199/**.

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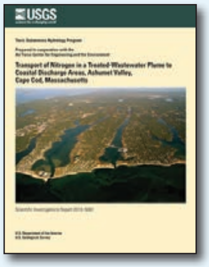
Land Use, Waste Sites, and Groundwater Quality

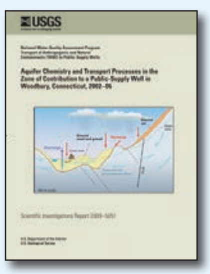
Similar to the Nation as a whole, groundwater concentrations of chloride, nitrate, and other constituents are trending upward in New England. These trends threaten aquatic ecosystems and drinking-water supplies. Increased road area and use of deicing chemicals, discharge of wastewater and septic systems, livestock waste and use of fertilizers, landfill leachate, and unmanaged hazardous waste sites are all potential sources needing further study in the region.

Sources of Groundwater Nitrogen to a Coastal Area of Cape Cod, Massachusetts



Land disposal of treated wastewater from a treatment plant on Cape Cod, Mass., has created a plume of contaminated groundwater that is migrating toward coastal discharge areas. Groundwater samples from two large sampling events in 1994 and 2007 were used to map the plume, calculate the masses of nitrate and ammonium, evaluate changes in mass since cessation of disposal in 1995, and create a gridded dataset suitable for use in simulations of nitrogen transport. Simulation results indicated that the total nitrogen loads from the treated wastewater plume are much lower (less than or equal to 11 percent) than corresponding steady-state nonpoint-source loads from the watersheds. ***Publication at*** **http://pubs.er.usgs.gov/publication/sir20135061**.

Aquifer Chemistry and Transport Processes Near a Production Well in Connecticut



The distribution and concentrations of various chemical constituents were used to identify recharge source areas, aquifer source material, anthropogenic sources, chemical processes, and groundwater-flow paths from recharge areas to a production well in Woodbury, Conn. Most groundwater samples contained some component of road salt or septic-system leachate, and most water that contributed to the public-supply well was young (less than 7 years) and derived from the glacial stratified deposits. Groundwater samples with the highest nitrate concentrations were obtained from wells downgradient from residential septic-tank drain fields; one well had an enriched nitrogen-15 value consistent with a septic-tank drain field source. ***Publication at*** **http://pubs.er.usgs.gov/publication/sir20095051**.

Effects of Remediation System on an Organic Contaminant Plume in New Hampshire

The Savage Municipal Well Superfund site in Milford, N.H., is underlain by a plume of volatile organic compounds (VOCs), mostly tetrachloroethylene (PCE), concentrations of which were detected in excess of 100,000 parts per billion in 1995. A remediation system was installed to contain and capture the dissolved VOC plume in a portion of the site. The remediation system includes a low-permeability barrier wall that encircles the highest detected concentrations of PCE and a series of injection and extraction wells to contain and remove contaminants. From 1998 to 2004, PCE concentrations decreased by an average of 80 percent at most wells outside the barrier wall. This decrease indicates that the barrier wall and interior extraction effectively contained high PCE concentrations inside the wall, other sources of PCE did not appear to be outside of the wall, and ambient groundwater flow in conjunction with the exterior remediation wells effectively remediated most of the dissolved PCE plume outside the wall. ***Publication at*** **http://pubs.er.usgs.gov/publication/sir20065083**.

Methyl *Tert*-Butyl Ether in Groundwater, Air, and Precipitation in Maine

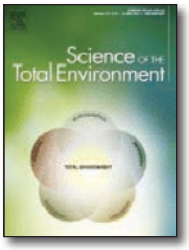
Wells in the sand and gravel aquifer in North Windham, Maine, were sampled from July 1998 to May 1999 for methyl *tert*-butyl ether (MTBE), which is a volatile, flammable liquid that gives water an unpleasant odor and taste. MTBE was detected in 35 percent of the wells sampled in the aquifer; the median of the concentrations detected was 1.13 µg/L. MTBE was detected in 64 percent of wells in the high-yield part of the aquifer. Land cover also was found to be associated with MTBE in groundwater in the study area, with urban and low-density residential areas having more MTBE than undeveloped areas. During the study, the use of MTBE in gasoline in Maine was restricted. Before the restrictions, median air concentrations of MTBE were 0.25 part per billion by volume (ppbv); after the restriction of MTBE, median concentrations dropped to 0.09 ppbv. Precipitation, however, could not account for the overall levels of MTBE in the aquifer. ***Publication at*** **http://pubs.er.usgs.gov/publication/wri20004048**.

U.S. Geological Survey scientists install a multilevel sampler in a sand and gravel aquifer on Cape Cod, Massachusetts. The sampler will help assess groundwater transport of nitrogen from a residential area to an adjacent coastal embayment. Photograph by the U.S. Geological Survey.

New Methods and Tools

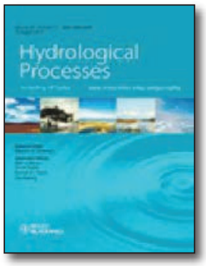
Innovative field, laboratory, and modeling methods are applied by the USGS to better understand and address groundwater contaminant challenges. State-of-the-art laboratories at the USGS provide the latest methods for analysis of major and trace elements, organic compounds, stable isotopes, groundwater-age tracers, microorganisms, and contaminants of emerging concern, such as pharmaceuticals and personal care products. New geophysical methods allow mapping of contaminant plumes, improved assessment of groundwater/surface-water interaction, logging of vertical contaminant distributions, and mapping bedrock surface topography beneath thick sand-and-gravel deposits, among other applications.

Hormones, Pharmaceuticals, and Other Micropollutants in Groundwater Affected by Septic Systems in New England



Septic-system discharges can be an important source of micropollutants (including pharmaceuticals and endocrine-active compounds) to adjacent groundwater and surface-water systems. Groundwater samples were collected from a well network in New England adjacent to a single large septic system that receives discharge from an extended health care facility for the elderly. The highest micropollutant concentrations from the New England network were present in samples collected below the leach beds and in a well downgradient of the leach beds. Concentrations for personal care, and domestic use, pharmaceutical, and plasticizer compounds generally ranged from 1 to more than (>) 20 µg/L in the New England network samples. High tris 2-butoxyethyl phosphate (TBEP) plasticizer concentrations in wells beneath and downgradient of the leach beds (>20 µg/L) may reflect the presence of this compound in cleaning agents at the extended health care facility. ***Publication at*** **http://dx.doi.org/10.1016/j.scitotenv.2014.12.067**.

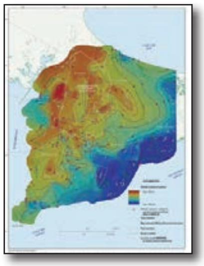
Mapping Road-Salt Contaminated Groundwater Discharge to Streams



Chloride concentrations in excess of the water-quality standard (230 milligrams per liter) determined by the State of New Hampshire have been measured in watersheds adjacent to Interstate 93 (I–93) in southern New Hampshire. A proposed widening plan for I–93 has raised concerns over further increases in chloride concentrations from road salt. As part of this effort, discharge of road-salt-contaminated groundwater was mapped with terrain electrical conductivity electromagnetic methods in fall 2006 to identify potential sources of chloride (during base flow conditions) to Policy Brook, a small stream in Salem, N.H. Results identified several stream reaches where high electrical conductivity groundwater may have been discharging. Based on the delineation of high (up to 350 millisiemens per meter [mS/m]) apparent terrain electrical conductivity, seven streambed piezometers were installed to sample shallow groundwater. Locations with high specific conductance (up to 2,630 mS/m) in shallow groundwater generally matched locations with high streambed (shallow subsurface) terrain electrical conductivity. A regression equation was used to convert the terrain electrical conductivity of the streambed to an equivalent chloride concentration in shallow groundwater at the site. ***Publication at*** **http://dx.doi.org/10.1002/hyp.7645**.

Mapping Aquifer Thickness and Bedrock Topography on Cape Cod

Characterizing the thickness of unconsolidated sand and gravel deposits overlying bedrock is essential for successful groundwater monitoring, modeling, and remediation at many glaciated sites. Western Cape Cod contains one of New England's largest groundwater contamination sites, and provided an ideal location for USGS to test the horizontal-to-vertical spectral-ratio (HVSR) method for quantifying overburden thickness. HVSR is based on the relationship between the resonance frequency of ambient seismic noise as measured at land surface and the thickness of the unconsolidated sediments that overlie consolidated bedrock. HVSR data for 164 sites on western Cape Cod were related to data from 559 borings to bedrock in the study area, using a statistical modeling approach. The results were manually contoured to prepare a topographic map of the bedrock surface. The interpreted bedrock surface generally slopes downward to the southeast as was shown on earlier maps. The surface also has newly revealed, complex small-scale topography characteristic of a glacially eroded surface. ***Publication at*** **http://pubs.er.usgs.gov/publication/sim3233**.

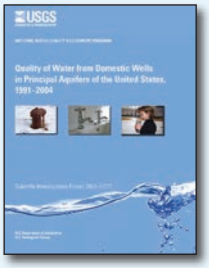


U.S. Geological Survey hydrologists collect groundwater samples from microwells pushed into the bottom sediments of a pond on Cape Cod, Massachusetts, during a tracer experiment to measure chemical and biological changes in water quality in an area where pond water is recharging the sand and gravel aquifer. Photograph by the U.S. Geological Survey.

Drinking Water Quality and Human Health

Although health-based water-quality standards exist for public-water supplies, private domestic wells are not regulated under Federal law or by most States. The USGS is working nationally and in New England to collect water-quality data from domestic wells and assess associated public-health risks.

Water Quality in Domestic Wells in New England and the United States



Physical properties and concentrations of major ions, trace elements, nutrients, radon, and organic compounds (pesticides and volatile organic compounds) were measured in domestic wells across the United States. About 23 percent of wells had at least one contaminant present at concentrations greater than a maximum contaminant level for public water supplies or a USGS health-based screening level, based on analysis of samples from 1,389 wells in which most contaminants were measured. In domestic wells completed in the crystalline bedrock aquifer in New England, concentrations of arsenic, fluoride, radon, and uranium were found to be elevated relative to most other areas of the Nation. ***Publication at*** **http://pubs.er.usgs.gov/publication/sir20085227**.

Potential Link Between Arsenic in Groundwater and Cancer Rates in New England

A study was conducted that related age-adjusted cancer mortality rates for white men and women from 1985 to 1999 to the proportion of persons using private water supplies in 1970. After adjusting for the effect of population density, there was a statistically significant positive correlation between residual bladder cancer mortality rates and private water-supply use among both men and women in New England (r=0.42 for men and r=0.48 for women) and in New York and New Jersey (r=0.49 for men and r=0.62 for women). Use of well water from private sources or a close correlate may be an explanatory variable for the excess bladder cancer mortality in New England. ***Publication at*** **http://jech.bmj.com/content/60/2/168.abstract**.

A U.S. Geological Survey scientist installs equipment for continuous monitoring of water levels and water quality in a bedrock well in New Hampshire. Photograph by the U.S. Geological Survey.

A core sample from the fractured bedrock aquifer underlying Great Bay National Wildlife Refuge in New Hampshire. Photograph by the U.S. Geological Survey.

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