Fact Sheet

United States Geological Survey
Toxic Substances Hydrology Program

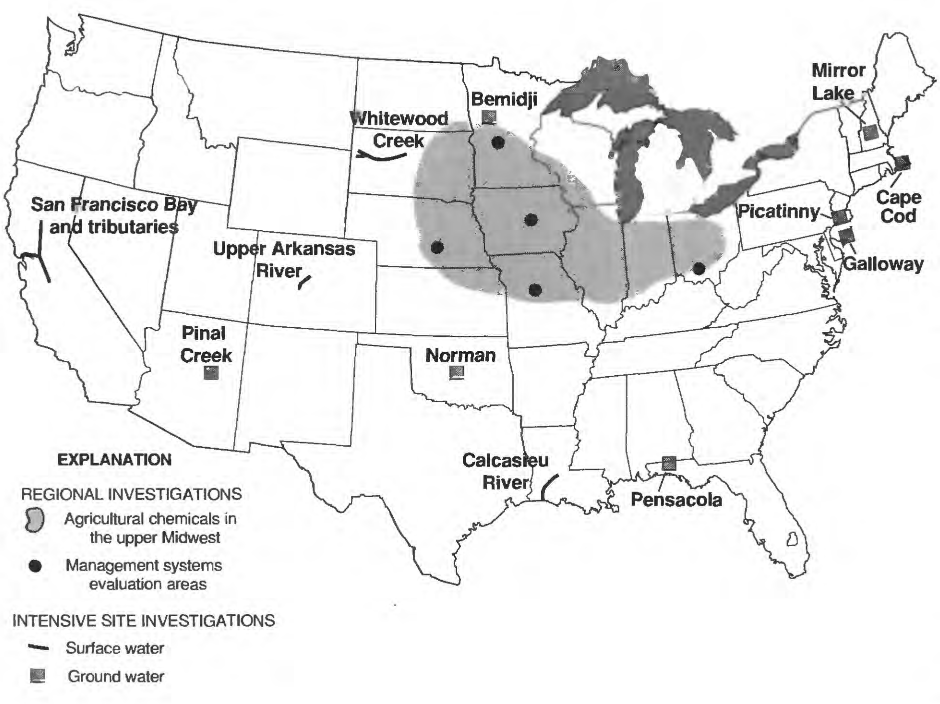
The USGS provides maps, reports, and information to help others meet their needs to manage, develop, and protect America's water, energy, mineral, and land resources. We help find natural resources needed to build tomorrow, and supply scientific understanding needed to help minimize or mitigate the effects of natural hazards and environmental damage caused by human activities. The results of our efforts touch the daily lives of almost every American.

The occurrence of toxic substances in surface and ground waters is a threat to human health and aquatic life. Contaminants from gasoline, pesticides, sewage, cleaning solvents, and trace metals are harmful to humans in very low concentra-tions. For example, 1 gallon of trichloroethylene (a cleaning solvent) can contaminate 290 million gallons of water beyond safe drinking-water limits. The General Accounting Office has stated, "the dimensions and potential costs of cleaning up our environment are so great that, without innovative technologies, we may find the solution cost prohibitive and impacting on our ability to address other national needs." By using current technologies, the costs of remediating Superfund and Resource Conservation and Recovery Act sites, Federal facilities, and other known hazardous waste sites may total $750 billion over the next 30 years.

In 1982, the U.S. Geological Survey (USGS) initiated the Toxic Substances Hydrology Program (Toxics Program). Its goal is to provide the unbiased earth science information on the behavior of toxic substances in the Nation's surface and ground waters that is needed to avoid human exposure, to develop effective remedial strategies, and to prevent further contamination. The program has three major components:

- **Intensive Site Investigations** of specific types of toxic substances
- **Regional Investigations** of the toxic substances related to typical land uses
- **Development of Methods** for the collection, analysis, and interpretation of data related to toxic substances

The objective is to develop practical methods and unifying principles that can be applied to solve major types of contamination problems nationwide.



Investigations of the USGS Toxic Substances Hydrology Program.

Accomplishments

Some noteworthy accomplishments of the Toxics Program are listed below. Information on how to obtain more information about the program, including a bibliography of scientific publications produced through 1993, is provided at the end of this fact sheet.

- Scientists working on gasoline and crude oil spills found that naturally occurring microbes degrade (break down) these contaminants at appreciable rates in the subsurface. This knowledge contributed to development of a remediation approach known as intrinsic bioremediation. By employing this approach, contaminants are contained onsite and are permitted to degrade naturally to nontoxic products. Intrinsic bioremediation costs much less than conventional "pump-and-treat" or "dig-and-remove" technologies.
- Scientists working at several sites have developed fundamental knowledge and mathematical models of the physical processes that cause contaminants to spread and dilute in the subsurface. The knowledge and models are being used nationally by regulatory agencies to guide the design of monitoring networks at contaminated sites and to improve the design of remedial strategies.
- Persistence of trichloroethylene (a cleaning solvent) on aquifer sediments makes remediation with conventional pump-and-treat technology impossible in a practical timeframe (several years). A technology that combines subsurface injection of nontoxic detergents with pumping and treatment is being evaluated at a field site. Initial results are encouraging—the resulting technology could substantially improve the efficiency of remediation.
- An investigation of agricultural chemicals in the Midwest demonstrated that herbicide contamination in rivers is related to applications in the spring

and is not a year-long problem. This knowledge will substantially reduce monitoring and treatment costs for utilities drawing raw water supplies from Midwestern streams and rivers.

- This same investigation found no exceedances of U.S. Environmental Protection Agency maximum contaminant levels or health advisory levels for sampled herbicides in shallow ground water under Midwestern corn and soybean fields. This information is being used in formulating policy for a new Farm Bill.
- The efficiency of biochemical tests to detect pesticides in surface and ground waters has been demonstrated widely in the field. The tests are rapid and inexpensive compared with traditional laboratory analysis and will enable more frequent testing over wider geographic areas. This will greatly improve the ability to develop and check strategies that are designed to prevent contamination through changes in application rates and timing.

Intensive Site Investigations

Field sites are selected to represent the principal types of contamination and geohydrologic conditions that exist across the Nation. In this manner, knowledge and methods developed at studied sites can be readily used by resource managers at other sites. Scientists from universities and other Federal agencies cooperate with the USGS at the field sites to develop and test methods and principles.

Cape Cod, Massachusetts

Treated sewage disposal has formed a plume of contaminated ground water about 2.5 miles long in a shallow sand and gravel aquifer near Cape Cod, Massachusetts. The plume contains chlorinated hydrocarbons, detergents, metals, nitrate, and microbes. Detailed sampling of the plume and large-scale tracer experiments are being used to develop models that will enable scientists to predict how contaminants spread in the subsurface and how quickly contaminants in sewage degrade to less toxic compounds. These methods are being used at other contaminated sites nationwide.

Bemidji, Minnesota

Crude oil from a pipeline rupture in 1979 contaminated a shallow aquifer near Bemidji, Minnesota. After initial cleanup, about 110,000 gallons of crude oil remains in the subsurface. This site thus provides a unique opportunity to study a contaminant plume where the location, amount, and timing of the spill are precisely known. The study focuses on how crude oil spreads in soil vapor and ground water. Models have been developed to describe the controlling physical, chemical, and biological processes. These models can be used to evaluate remedial strategies for crude oil spills, including intrinsic bioremediation.

Galloway, New Jersey

Gasoline from a leaking underground storage tank in Galloway, New Jersey, has contaminated a shallow sand aquifer. Investigators have developed methods to determine the rates at which gasoline degrades to less toxic compounds in the subsurface and to simulate the movement of gasoline vapors in soil by using computer models. These methods are used to evaluate the potential for intrinsic bioremediation and to design remedial strategies for gasoline in the subsurface. Nationwide, leaking underground petroleum storage tanks threaten shallow ground-water supplies and allow gasoline vapors to move into basements.

Picatinny, New Jersey

Trichloroethylene (TCE), which is a common cleaning solvent and degreaser, has contaminated a sand and gravel aquifer near Picatinny, New Jersey. Investigations have focused on measuring natural processes that are removing TCE from ground water (such as degradation by microbes and loss as vapors to the atmosphere), identifying causes for the persistence of TCE in the aquifer, and field testing new remediation technologies.

San Francisco Bay and Tributaries, California

Diverse organic and inorganic contaminants that vary widely in their environmental behavior, sources, and toxicity enter the San Francisco Bay estuary. Toxic substances enter the estuary in agricultural and urban runoff and in discharges from municipal wastewater facilities and industries. The study focuses on the movement, fate, and effect of pesticides, petroleum hydrocarbons, and toxic trace elements and the effects of the highly varying hydrologic conditions in river–estuarine environments. Scientists are developing an approach to characterize the distribution of contamination and the resulting ecological effects that will be applied in similar environments elsewhere.

Mirror Lake, New Hampshire

Fractured-rock aquifers near Mirror Lake, New Hampshire, have highly varied and complex hydrologic characteristics. They are widely distributed near land surface and are frequently affected by contamination. Uncertainty in the rates and paths of ground-water movement in fractured rock commonly prevents the identification of human and environmental risks and the determination of effective remedial strategies. USGS scientists are developing methods to characterize the movement of water and contaminants through fractured rock. For example, subsurface radar is being used to map discrete fractures that could provide rapid pathways for contaminant

Collecting ground-water samples from multiport samplers during a tracer test at the field site at Cape Cod, Massachusetts.

migration. The use of methods developed at this site will greatly improve the ability to predict the movement of toxic substances and to design remedial strategies at similar sites elsewhere.

Upper Arkansas River Basin, Colorado

Metals enter the Arkansas River in acidic mine drainage and runoff from mine wastes and tailings in the Leadville, Colorado, area. The metals and acidic conditions are toxic to aquatic life. Scientists have studied the mechanisms of metal transport and transformation in streams affected by mine drainage. Now, efforts are focused on using this knowledge to determine effective remedial methods.

Pinal Creek, Arizona

Dissolved metals in high concentrations are moving in an acidic plume through a shallow aquifer downstream from a copper mining area near Pinal Creek, Arizona. Chemical reactions that change the form and nature of metals in the ground-water plume are being studied. Movement of metals from ground water into the stream and chemical reactions in the stream also are being studied. The investigation has used field and laboratory techniques and geochemical modeling to identify hydrologic processes in the plume and the creek that determine the effectiveness of remediation efforts.

Calcasieu River, Louisiana

Petrochemical wastes have contaminated the river and estuarine environment along the Lower Calcasieu River in Louisiana. The wastes include volatile organic compounds (like gasoline) and chlorinated organic compounds (like chloroform). This study, now concluded, focused on the movement and transformation of these toxic chemicals in water, bottom sediments, and aquatic organisms. A brackish-water clam, *Rangia cuneata,* was used to detect contaminants at concentrations below analytical detection limits. Information on the occurrence of contaminants and mechanisms of their remobilization from bed sediments have affected the design of dredging operations and the issuing of permits for industrial discharges.

Pensacola, Florida

Wood preservatives (creosote and pentachlorophenol) were discharged into two unlined pits near Pensacola, Florida, for more than 80 years. The contaminants seeped into an underlying sand and gravel aquifer and created an underground waste plume 1,000 feet long. This study, now concluded, focused on the occurrence, transport, and degradation of organic contaminants associated with the wood preservatives. The study demonstrated the ability of naturally occurring microorganisms to degrade many of the organic contaminants to less toxic compounds.

USGS and U.S. Environmental Protection Agency scientists collecting aquifer-material samples using an anaerobic chamber at Picatinny Arsenal, New Jersey.

Whitewood Creek, South Dakota

Mining wastes from the processing of gold ore were deposited in Whitewood Creek, South Dakota, for more than 100 years. About 100 million tons of finely ground gold-mill tailings, containing arsenic and other trace elements, mixed with natural sediments and were deposited in channels and flood plains downstream. This study, now concluded, characterized the downstream dispersal of contaminants through water movement, sediment transport, transfer of contaminants from sediments to water, and uptake of contaminants by aquatic organisms. Information gathered helped evaluate the long-term threat of the contaminants to the stream ecosystem and to downstream water supplies.

Norman, Oklahoma

Landfill leachate has contaminated ground water in an alluvial aquifer adjacent to the Canadian River near Norman, Oklahoma. The landfill accepted municipal wastes for more than 60 years until it closed in 1985. Ground water at the site is contaminated by dozens of organic compounds, many of which are toxins and carcinogens. Investigations will focus on the interactions between the contaminant plume, the aquifer, and the river. The study results will be readily transferable to numerous municipal landfills across the country.

Regional Investigations

Regional investigations are designed to evaluate the effects on water quality of land uses that are found over broad geographic areas. The success of regional investigations is assured by the presence of a staff of USGS hydrologists in every State who are trained to use nationally consistent methods and to collect accurate and reproducible hydrologic data.

Agricultural Chemicals in the Upper Midwest

The occurrence, transport, and fate of agricultural chemicals is being studied in a 12-State area in the upper Midwest. Scientists are identifying factors that affect dispersal of these chemicals in surface and ground waters from point of application and are evaluating the resulting effects in small streams and large rivers, at reservoir outfalls, in shallow ground water, and in precipitation. The goal is to provide the general scientific basis needed to develop agricultural

USGS scientists collect water samples from the Calcasieu River, Louisiana.

management practices that protect the quality of the region's water resources.

Management Systems Evaluation Area Program

The USGS is participating with the U.S. Department of Agriculture, U.S. Environmental Protection Agency (USEPA) and other Federal and State agencies to evaluate the effects of different farming systems. Investigations are being conducted in five Management Systems Evaluation Areas—in Missouri, Minnesota, Nebraska, Ohio, and Iowa. The goal is to reduce the effect of agriculture on surface- and ground-water quality through implementation of improved farming practices.

Land-Use Studies

An investigation of 14 study areas was undertaken in 1984 to identify relations between land uses and ground-water quality and to test the transferability of these relations to other areas. The areas selected were representative of typical land uses and hydrogeologic terrains. Detailed investigations conducted at 7 of the 14 original sites resulted in statistical methods that are used to identify specific relations. Methods developed in these studies are being applied today in the USGS National Water Quality Assessment Program. The methods also are being applied by the USEPA and State agencies to develop vulnerability models that will produce substantial cost savings from reduced monitoring of public ground-water supplies required under the Safe Drinking Water Act.

Methods Development

Scientific methods developed as part of the Toxics Program include the following:

- **Innovative approaches** used to characterize and remediate contamination that are based on new scientific principles
- **Computer simulation models** used to improve basic understanding of processes and to test remediation
- **Field and laboratory methods** used to collect data

Hypotheses related to physical, chemical, and microbial processes are developed. After being tested under field and (or) laboratory conditions, successful hypotheses provide new scientific principles that explain the occurrence, movement, and ultimate fate of contaminants in the environment. As an example, scientists hypothesized that trace amounts of chlorofluorocarbons (a chemical used in aerosols) dissolved in ground water could be used to define accurate ages of ground water (the length of time that water has resided in the ground). The resulting **innovative approach** is being applied to help solve regional and site-specific ground-water-quality problems.

Computer simulation models are developed to represent the physical, chemical, and biological processes that control the movement and fate of toxic substances. These models are then used as general tools to quantify process rates, test new hypotheses, and evaluate remedial strategies. Examples include models that simulate the movement of dissolved contaminants in ground water, the movement of contaminants as vapor in the subsurface, and geochemical and biological reactions involving multiple contaminants. The models are tested at the field sites to confirm their validity.

As our understanding of the processes that affect contamination problems increase, so do demands for **field and laboratory methods** that can be used to collect additional types of data on toxic substances at different scales. Increased reliability and lower cost for collecting, preparing, and analyzing samples also is demanded. Examples of such methods developed by the Toxics Program include field sampling methods for volatile organic compounds in ground water and new analytical methods for determining the products of pesticide breakdown in water.

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Additional earth science information can be found by accessing the USGS "Home Page" on the World Wide Web at "http://www.usgs.gov".

For more information on all USGS reports and products (including maps, images, and computerized data), call 1-800-USA-MAPS.

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