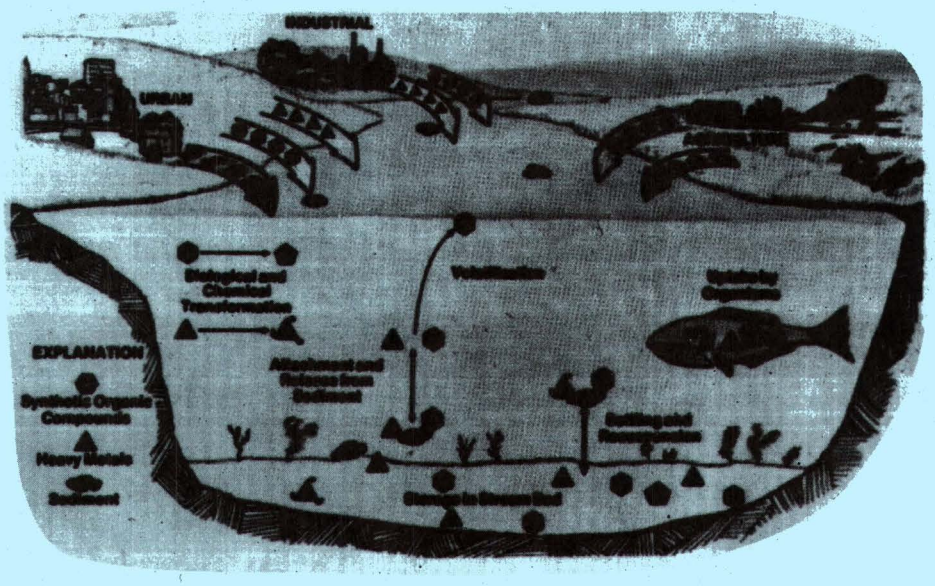
Bibliography of Publications From the Toxic Substances Hydrology Program, U.S. Geological Survey



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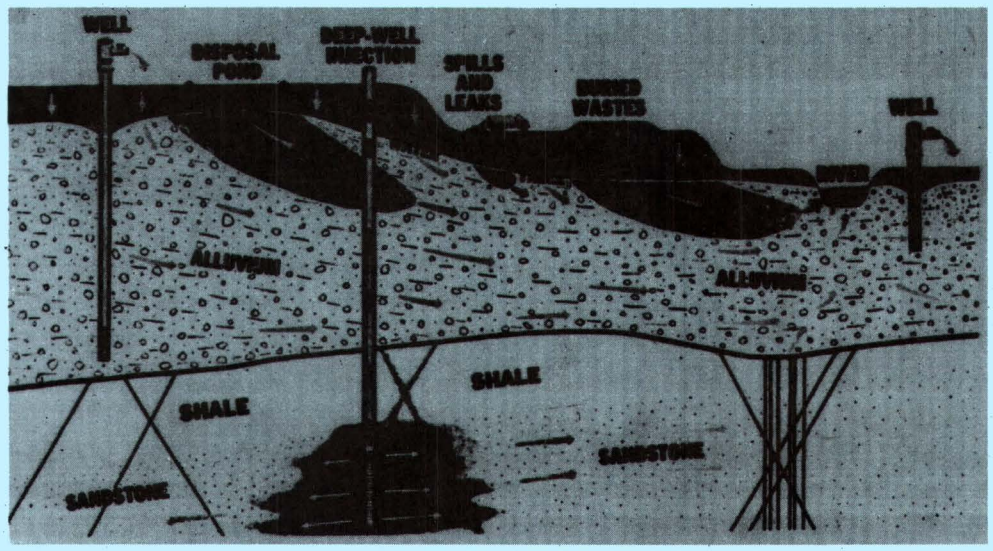

Bibliography of Publications From the Toxic Substances Hydrology Program, U.S. Geological Survey

By David W. Morganwalp, Compiler

U.S. GEOLOGICAL SURVEY

Open-File Report 94-91

Tallahassee, Florida
1994

U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

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Bibliography of Publications From the Toxic Substances Hydrology Program, U.S. Geological Survey

By David W. Morganwalp, Compiler

Abstract

The U.S. Geological Survey began the Toxic Substances Hydrology Program in 1982 to study, in an interdisciplinary atmosphere, the fate and effects of toxic substances in the environment. The objective of the Program is to provide the earth-science information needed to prevent or mitigate contamination of the Nation's ground and surface waters. To achieve this goal, research is conducted in four categories—focused field investigations of contaminated sites, additional research on toxic substances hydrology, development of methods to study or sample contaminated waters, and investigations of nonpoint sources of contamination. This report contains citations of reports on research conducted under the auspices of the Program from the beginning of the Program through the end of 1993.

Introduction

In many areas, contamination from point and nonpoint sources has impaired the quality of the Nation's ground and surface waters. To design efficient and cost-effective ways to prevent and cleanup contaminated waters, an understanding of the processes that control the transport and fate of contaminants is needed. Methods for sampling contaminated water and investigative approaches to characterize contaminated sites also are needed. The U.S. Geological Survey began the Toxic Substances Hydrology Program in 1982 to study, in an interdisciplinary atmosphere, the fate and effects of toxic substances in the environment.

The objective of the Toxic Substances Hydrology Program is to provide the earth-science information needed to understand the transport and fate of toxic substances in the Nation's ground and surface waters. To achieve this goal, research is conducted in four categories—field investigations of contaminated sites, additional research on toxic substances hydrology, development of methods to study or sample contaminated waters, and investigations of nonpoint sources of contamination.

This report contains citations for reports resulting from the program that describe the results of studies from the beginning of the program through the end of 1993. Publications were included if research conducted at a Toxic Substances Hydrology Program site was the subject matter of the publication or if the publication reported on research funded by the Program, but was not conducted at a Program site. Publications that described research conducted at a Program site not funded by the Program also were included. However, abstracts were not included. The report is divided into several major sections, each of which is described in the introduction to the section. Many of the section introductions are based on written material provided by researchers who are working at Toxic Substances Hydrology Program sites, and their publications appear in the bibliography.

Field Investigations of Ground- and Surface-Water Contamination

Field investigations are conducted at sites where applied and basic research and methods development activities are conducted at places known to be contaminated by common types of contaminants. The sites function as field laboratories where process-oriented research is conducted in an interdisciplinary environment. The objective of the research is to gain knowledge that is transferable to other areas or sites with similar contamination problems. Therefore, the primary emphasis at a particular field investigation site is not on the site itself, but on the development of sampling methods for particular contaminants, investigative methods or approaches, and an understanding of contaminant transport processes.

The following sections list the publication of past and current field investigations.

Sewage-Contaminated Water on Cape Cod, Massachusetts

Land disposal, which is commonly used to dispose of untreated and treated wastewater in the United States, can result in degradation of ground-water quality. To gain an understanding of the processes that control the migration of wastewater in ground water, the Toxic Substances Hydrology Program initiated a study at one site on Cape Cod, Massachusetts. The research site is located near Falmouth, Massachusetts, where the disposal of treated sewage in infiltration beds at Otis Air Base has created a plume of contaminated ground water in a sand-and-gravel aquifer. The rapid infiltration of wastewater since 1936 has resulted in a plume that is more than 4 kilometers long. Researchers from the U.S. Geological Survey and other institutions are studying the hydrologic, chemical, and microbiological processes that affect the fate of the dissolved contaminants in this plume. The research has focused on the effects of spatial variability of aquifer properties and the steep geochemical gradients within the plume on the transport, dilution, and transformation of contaminants. Tracer experiments have been used extensively at the site to investigate processes that control the transport of contaminants in the heterogeneous sand-and-gravel aquifer. The tracer experiments have involved the injection of nonreactive and reactive solutes, microbes, and microspheres into the aquifer. In addition, the site has been used to test ground-water sampling, drilling, and coring methods.

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Crude Oil in the Subsurface Environment at Bemidji, Minnesota

Contamination of ground water caused by the release of hydrocarbons from leaking underground storage tanks, fire training areas, pipeline failures, and other releases to the environment is a problem throughout the United States. To gain a greater understanding of the processes that control the movement of these nonaqueous phase liquids, the U.S. Geological Survey Toxic Substances Hydrology Program initiated a multidisciplinary research project at the site of a crude-oil pipeline failure that occurred on August 20, 1979, near Bemidji, Minnesota. After cleanup efforts were completed at this site, 400,000 liters of crude oil remained in the unsaturated zone and in the underlying glacial outwash aquifer. This site has provided a unique opportunity for researchers from the U.S. Geological Survey and other institutions to study a contaminant plume where the source is well documented and the plume is located in a remote area. The objectives of research at this site are to obtain an understanding of the transport and fate of petroleum derivatives in the subsurface, and to use this understanding to develop predictive models of contaminant transport. The emphasis of the research has been to characterize the hydrogeochemical environment, identify the controlling geochemical reactions, and investigate the multiphase flow of crude oil.

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Creosote Waste in Ground Water Near Pensacola, Florida

Ground-water and surface-water contamination by wood preservatives (such as creosote and pentachlorophenol) is a common problem. In 1983, a creosote works near Pensacola, Florida, was selected by the U.S. Geological Survey's Toxic Substances Hydrology Program to gain an understanding of the processes that control the transport of organic contaminants in ground water. Pine poles were treated with wood preservatives at this site from 1902 to 1981. Creosote, diesel fuel, and pentachlorophenol were discharged to two unlined impoundments that had a direct hydraulic connection to an underlying sand-and-gravel aquifer. This activity created a waste plume that extends downgradient in the upper part of the sand-and-gravel aquifer for approximately 300 meters south toward Pensacola Bay. The focus of this multidisciplinary research project was an investigation of the processes that affect the occurrence, transport, transformation, and fate of the toxic contaminants associated with wood preservatives. Researchers investigated the transport, sorption, dispersion, biodegradation, and geochemistry of these complex organic wastes.

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Chlorinated Solvents in Ground Water at Picatinny Arsenal, New Jersey

Contamination of ground water by chlorinated solvents is a major problem because these compounds are used in many different industrial and commercial processes, including metal degreasing, dry cleaning, fumigation, and organic synthesis, and because these compounds are relatively soluble compared to other synthetic organic contaminants. Under the auspices of the Toxic Substances Hydrology Program, U.S. Geological Survey researchers are conducting an interdisciplinary study of the transport and fate of chlorinated solvents at Picatinny Arsenal in north-central New Jersey. From 1960 to 1985, chlorinated solvents, primarily trichloroethylene (TCE), entered the unconfined glacial sand-and-gravel aquifer at this site through two unlined wastewater lagoons and a dry well and created a plume of TCE-contaminated ground water. Research at the Picatinny site has focused on the following major areas: (1) the transport of chlorinated solvents in the unsaturated zone, (2) the microbial transformation of chlorinated solvents in the saturated zone, (3) the solute-transport modeling of chlorinated solvents in the saturated zone, (4) the chemical processes affecting transport of chlorinated solvents in the saturated zone, and (5) the evaluation of remediation processes for chlorinated solvents in the saturated and unsaturated zones.

More specifically, researchers at this site have investigated the following:

- The effect of soil moisture on TCE-vapor sorption to unsaturated-zone soil,
- The fate of TCE vapors that volatilize from the water table during an infiltration event,
- The rates of microbially mediated reductive dechlorination of TCE and cis-1,2-dichloroethylene that occur naturally in the aquifer,
- The use of a reactive multispecies solute-transport model to predict and understand the transport of TCE and its breakdown products in ground water,
- The rate of TCE-desorption from aquifer sediments exposed to long-term TCE contamination,
- The feasibility of using aerobic cometabolic biotransformation of TCE as a remediation process in the unsaturated zone, and
- The use of surfactants to enhance desorption of TCE from aquifer sediments during pump-and-treat remediation.

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Gasoline in Ground Water in Galloway Township, New Jersey

The United States is faced with the cleanup of thousands of leaking underground storage tanks, most of which contain gasoline. To provide industry, regulators, and the public with a better understanding of the processes that control the movement of the components of gasoline in the subsurface, U.S. Geological Survey researchers initiated a study under the auspices of the Survey's Toxic Substances Hydrology Program at the site of a leaking underground gasoline tank in Galloway Township, New Jersey.

The objectives of this interdisciplinary study are to develop field and laboratory methods to quantify the factors that control hydrocarbon transport and microbial degradation in the subsurface and to develop mathematical models of the governing processes. Natural and remediation conditions are under investigation.

Field and laboratory methods for estimating the rate of microbial degradation of hydrocarbons based on vapor transport in the unsaturated zone have been developed along with the mathematical models required to analyze the data from these experiments. Mathematical models have been developed to optimize hydrocarbon vapor-extraction remediation systems. An extensive water-quality data base, which has been used to interpret the anaerobic and aerobic degradation of hydrocarbons that occur under natural conditions, exists for the site.

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Organic Compounds in the Lower Calcasieu River, Louisiana

Many rivers, estuaries, and streams in the United States receive effluent discharges from petrochemical plants. This practice has resulted, in many cases, in the occurrence of hazardous organic chemicals and trace elements in water, bottom sediments, and aquatic organisms. To gain a better understanding of the fate of hazardous organic chemicals in surface-water environments, the U.S. Geological Survey's Toxic Substances Hydrology Program initiated an investigation of the lower Calcasieu River in Louisiana.

Many petrochemical plants are located along the lower Calcasieu River. These plants use the river for effluent discharge, cooling water supply, and transportation. The investigation involved a multidisciplinary approach to define the fate and transport of trace metals, volatile organic compounds, and chlorinated organic compounds in an estuarine environment. The study team investigated the movement of toxic chemicals in water, suspended sediment, bottom material, and tissue samples. Other studies looked at the characteristics of naturally occurring organic compounds in freshwater and saltwater and the uptake of contaminants by a brackish water clam from uncontaminated areas to define downstream movement of chlorinated compounds in areas where contamination was not detectable in bottom material and water samples. Studies looked at remobilization of synthetic organic compounds from bottom material exposed to different ionic strength waters that might be present during dredging activities and at potential movement of contaminants from sediments to the water column by exchange of interstitial water across the sediment-water interface. Also, toxicity tests that use a marine amphipod were run in association with chemical tests to determine the impacts on biota of priority pollutants in this estuary. Tracer studies and a hydrologic model were developed to understand contaminant movement within the study area.

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The Fate of Anthropogenic Contaminants in the San Francisco Bay Estuary and Tributaries, California

The San Francisco Bay Estuary, California, receives a diverse group of anthropogenic contaminants that vary widely in their environmental behavior, sources, seasonality, and toxicity. The objectives of this project are to (1) determine how contaminants from riverine and local sources are transported and transformed under varying hydrologic conditions, (2) determine the ultimate fate of these contaminants, and (3) develop approaches to detect or quantify ecological responses to the presence of contaminants in this river-estuary system. More specifically, this project has included studies on (1) the fate of pesticides discharged into the San Francisco Bay's river-estuary system, (2) the fate and distribution of organic contaminants in bay sediments, (3) the history of organic, as well as inorganic, contaminants in the bay, and (4) the adverse effects of trace metals on benthic aquatic organisms.

The primary determinants of organic contaminant distribution, such as pesticides, in the river-estuary system are considered to be the geographic location of the pesticide source(s), the biogeochemical properties of the pesticides, and the hydrology of the system. Field studies measure the distribution of pesticides in the water column, sediments, and biota. When combined with laboratory studies of the biogeochemical properties of the pesticides and hydrodynamic modeling, these results can be used to predict distributions of organic contaminants under different conditions or in other environments.

Other geochemical studies of San Francisco Bay have included an aerial survey of surficial bay sediments to determine concentrations and distributions of dichloro-diphenyl-trichloro-ethane (DDT), DDT metabolites, polychlorinated biphenyls (PCB's), polycyclic aromatic hydrocarbons (PAH's), aliphatic biomarkers (indicative of anthropogenic petroleum contamination), and other hydrocarbons. This mixture of organic compounds provides information on sources of organic input into the San Francisco Bay.

In another study, which was partially funded by the National Oceanographic and Atmospheric Administration, a collaborative effort has examined the historic profile of organic, as well as inorganic, contaminants in the San Francisco Bay sediments. Two cores with unbroken sedimentary records, one from Richardson Bay and the other from San Pablo Bay, have shown the transition from the preindustrial to the industrial era. This transition is clearly observed by an increase in concentrations of anthropogenic contaminants.

The biological effect, spatial distributions, and temporal trends of trace metal contamination in the San Francisco Bay are being investigated by using bottom sediments and benthic organisms. The specific objectives of this study are to characterize biochemical, physiological, and population variables that are potential indicators of toxic effects; investigate marginal environmental conditions, such as salinity changes, that enhance the toxicological effects of trace metals; and investigate biological processes, such as the selection of tolerant species or populations, that reduce the sensitivities of aquatic organisms to trace metals.

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Ground-Water Contamination by Heavy Metals Near Tar Creek, Oklahoma

Years of mining for heavy metals has resulted in abandoned mines that are a source of ground- and surface-water contamination in many areas of the United States. To gain an understanding of the controlling processes in the transport of heavy-metal contaminants, which can be applied at other sites, the U.S. Geological Survey's Toxic Substances Hydrology Program initiated an investigation of the fate of heavy-metal contamination from abandoned lead and zinc mines in the Tar Creek drainage basin in northeastern Oklahoma and southeastern Kansas. Investigators from several disciplines studied the geochemical and microbiological reactions that mobilize iron, zinc, cadmium, lead, manganese, and nickel in the underground mine workings and the effect of transport and deposition of these metals in the surface-water drainage. Specific studies included modeling to determine the important geochemical reactions that control mine- and surface-water composition, investigating microbiological activity in surface water, and studying the biological uptake of metals by plants.

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Acidic Ground-Water Contamination from Copper Mining Near Pinal Creek, Arizona

Active and abandoned metal mines are a source of ground-water and surface-water contamination in many areas of the United States. To gain an understanding of the processes that control the transport of heavy-metal contaminants and acidic ground water, the U.S. Geological Survey's Toxic Substances Hydrology Program initiated an investigation of an acidic plume of contaminated ground water. The plume is in an alluvial aquifer along Miami Wash and lower Pinal Creek (Gila County, Arizona) and discharges to a perennial stream. The site is downstream from a major copper-mining district and upstream from a reservoir used for public water supply in Phoenix. The objective of this investigation is to determine the processes that control the transport of metals through the aquifer and into the perennial stream. Research at the site has used field and laboratory investigations and computer geochemical modeling techniques to identify many of the important reactions and processes that occur in the plume and in perennial streamflow. As the plume moves downgradient, it is neutralized through reaction with carbonate minerals and bicarbonate. Some metal contaminants are retarded by solid-aqueous partitioning reactions at the pH front, whereas other contaminants are easily transported in neutralized plume water ahead of the pH front. The contaminant load in neutralized water is discharged to Pinal Creek, where a proportion of the metals is partitioned to solid phases on the streambed. The acidic core of the plume may eventually reach the stream. Ongoing research seeks to constrain the large uncertainties in modeling hydrogeochemical processes at the site. The strengths and limitations of existing computer codes to simulate the observed geochemistry accurately are being tested. Data limitations are being addressed through detailed study of critical redox reactions and metal-partitioning reactions between solid and aqueous phases. Estimates of chemical mass balances at the site are being combined with results of ground-water age dating and solute tracer studies to constrain and improve hydrogeochemical models.

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Metals in the Headwaters of the Upper Arkansas River, Colorado

Years of mining in the Leadville, Colorado, area have resulted in acid mine drainage and runoff from numerous piles of mine wastes and tailings that contribute heavy metals to the Arkansas River. These metals are exerting a toxic effect on aquatic life. Studies of this system have provided valuable insight into the mechanisms of metal transport and transformation in streams affected by mine drainage. Instream transformation processes that affect metals, including precipitation, dissolution, sorption, and photoreduction have been studied in the context of tracer-dilution experiments to define hydrologic transport. These experiments, mostly conducted in St. Kevin Gulch, which is an acidic, metal-rich stream that is a tributary to the Arkansas River, have provided an opportunity to develop simulation models of reactive solute transport. Efforts are now shifting to investigations related to the response of St. Kevin Gulch to planned remediation. The results of these investigations can be applied to many areas in the United States where abandoned metals mines are contaminating surface water.

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Arsenic Contamination in the Whitewood Creek-Belle Fourche River-Cheyenne River System, Western South Dakota

Standard practice in the past was to discharge mining waste to the most convenient river or stream. This practice has resulted in the degradation of surface-water quality by leaching of toxic trace elements associated with alluvially deposited mine wastes. An understanding of the fate of arsenic and heavy metals in stream sediments is needed to effectively remediate or prevent surface-water contamination. To investigate the effect of contaminated stream sediments and mine-waste discharges and drainage, the U.S. Geological Survey's Toxic Substances Hydrology Program initiated a study of arsenic contamination in the Whitewood Creek-Belle Fourche River-Cheyenne River System, western South Dakota.

Between 1876 and 1977, finely ground mill tailings were discharge to Whitewood Creek. This activity resulted in alluvial flood-plain sediments that contain high concentrations of arsenic and trace metals. The objectives of this project were to investigate the distribution, transport, and ultimate fate of arsenic and trace metals in the contaminated sediments of the river system, the partitioning of trace metals between solid phases and dissolved phases in the system, and the effect of arsenic and trace metals on the ecology of the river system. An interdisciplinary team of researchers investigated the partitioning of arsenic between arsenopyrite (FeAsS) and iron hydroxides in streambed sediments and suspended sediments, the identification of colloids in alluvial seeps along Whitewood Creek, the bioaccumulation of arsenic by benthic invertebrates, and other related topics.

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Research on Flow and Transport in Fractured Rock at Mirror Lake, New Hampshire

Cleaning contaminated ground water and conducting water-quality investigations in fractured rock are daunting tasks because very few tools are available to characterize or predict contaminant transport in fractured rock. The goal of the research project at the Mirror Lake site in New Hampshire is to develop field techniques and interpretive methods for characterizing fluid movement and chemical transport in fractured rock aquifers. The field techniques and interpretive methods are to be developed from correlating information from a variety of hydrogeologic investigative techniques, including fracture and lithologic mapping, surface and borehole geophysics, hydraulic and tracer testing, geochemical and isotopic analyses, and ground-water flow and transport modeling. Because of the extreme spatial heterogeneity of fractured rock, two equally important scales of investigation have been developed as part of the fractured rock research project. The first scale of investigation is geared toward the characterization of flow and transport processes over length dimensions that are significant to point sources of contamination in fractured rock. Two dense clusters of wells (experimental well fields) have been developed for this purpose. The second scale of investigation involves characterizing flow and transport processes in fractured rock over larger length dimensions. This second scale of investigation is important in identifying approaches for placing point sources of contamination into a regional hydrogeologic framework that is based on sparse, spatially distributed data. A series of aerially distributed bedrock wells in the Mirror Lake watershed has been installed for this purpose.

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Research From the Irrigation Drainage Program

In response to concerns expressed by the U.S. Congress and environmental organizations over selenium contamination at the Kesterson National Wildlife Refuge in California, the Department of the Interior initiated a program in 1985 to identify the nature and extent of irrigation-induced water-quality problems that might exist in other irrigated areas of the Western United States. The program is concerned with irrigation or drainage facilities constructed or managed by the Department, national wildlife refuges managed by the Department, and other migratory-bird or endangered-species management areas that receive water from projects funded by the Department. The program has the following phases associated with each area: (1) site identification, (2) reconnaissance investigations, (3) detailed studies, (4) planning, and (5) remediation. Projects conducted under the first three phases are carried out by interdisciplinary study teams composed of researchers from the U.S. Geological Survey, the U.S. Fish and Wildlife Service, the U.S. Bureau of Reclamation, and the U.S. Bureau of Indian Affairs. A U.S. Geological Survey researcher is project chief for each of the interdisciplinary study teams. The U.S. Geological Survey participates in the last two phases under a Memorandum of Understanding with the U.S. Bureau of Reclamation.

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Subsurface Injection of Liquid Waste in Florida

Subsurface injection of liquid waste is the emplacement of waste liquids associated with manufacturing, sewage treatment, petroleum production, and other activities for disposal purposes into porous geologic formations. The emplacement is accomplished by pumping wastes down a well designed for waste disposal. Some wastes, such as highly concentrated acids used in the steel industry, require wells made of specialized alloy or fiberglass construction materials. Sandstones, unconsolidated sands, and fractured and solution-riddled limestones are the typical geologic formations that are used to dispose of liquid waste.

In 1963 the U.S. Geological Survey began investigating the effects of subsurface injection of liquid wastes from industrial and municipal sources in Florida. The reports from these studies cover the characterization of the hydrogeology of the injection well sites and potential injection intervals, description of the injection wells, and the geochemical and hydraulic effects of waste injection. Of particular note are studies that describe the reactions of the injected waste with the receiving formations and the native ground water. These studies have been funded in part by the Federal-State Cooperative Program of water resources studies and in part by the U.S. Geological Survey Toxic Substances Hydrology Program and predecessor Federal programs from 1970 to 1991.

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This section contains important research that was funded by the Toxic Substances Hydrology Program, but does not fit into any of the other sections in this bibliography. Most of this research was conducted by the National Research Program, which is a part of the U.S. Geological Survey's Water Resources Division, with funding from the Toxic Substances Hydrology Program. The National Research Program conducts basic and applied research in support of the mission of the U.S. Geological Survey. Funding from the Toxic Substances Hydrology Program is used for research on such topics as research on solute transport theory and the effects of toxic substances on the environment. This section contains publications written on projects that are not involved with Toxic Substances Hydrology Program sites. This includes a diverse set of topics that deal with the ecology of toxic substances, ground- and surface-water hydrology, and ground- and surface-water geochemistry.

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Methods Development

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Investigations of Contamination From Nonpoint Sources

Research on nonpoint-source contamination in the Toxic Substances Hydrology Program is conducted on many fronts. The overall objective of the research is to improve the understanding of important controls on the movement of contaminants from the point of application or use to ground water and surface water. It is expected that this understanding will provide the general scientific basis to protect the quality of the Nation's water resources. This part of the bibliography contains sections on regional reconnaissance studies on the occurrence of agricultural chemicals in the Midcontinent of the Unites States; research from the five Management Systems Evaluation Areas, where researchers are studying the environmental impact of alternative farming systems; research on the nonpoint sources of contaminants in relation to land use; an investigation of nonpoint-source ground-water contamination and its impact on the Cedar River, Iowa; and an investigation of the fate of agricultural chemicals in ground water near Plains, Georgia.

Research on Agricultural Chemicals in the Upper Midwest

In 1989, under the auspices of the Toxic Substances Hydrology Program, the Midcontinent Initiative was begun to study the fate of agricultural chemicals in the Nation's corn- and soybean-producing region. The overall purpose of the initiative is to improve the understanding of factors that control the movement of agricultural chemicals from the point of application to ground water and surface water. It is anticipated that this understanding will provide the general scientific basis to help develop agricultural management practices that will protect the quality of the Nation's water resources.

Research in the Midcontinent of the Unites States focused on the occurrence, movement, and fate of agricultural chemicals. A series of regional reconnaissance studies were done to determine the temporal and spatial patterns of occurrence of nitrate and selected herbicides in surface water, precipitation, ground water, and surface-water reservoirs.

Surface Water.—Several reconnaissance studies were conducted to look at different aspects and scales of surface water in the Midcontinent of the United States. A reconnaissance of 122 small river basins in the Midcontinent was conducted from 1989 to 1990. Water samples were collected from 149 sites in these basins to determine the concentration of nitrates and selected herbicides in surface waters before and after the spring application of agricultural chemicals. The samples resulted in a series of "snapshots" that demonstrated a spring flush of herbicides from agricultural fields in the Midcontinent area. This reconnaissance was followed by an intensive temporal sampling of nine small basins that were selected from the original 122 and a series of temporal samplings of the Mississippi River and its major tributaries. Samples also were collected from the Mississippi River during the flooding of 1993 in the Midwest, which also demonstrated the spring flush of herbicides from agricultural fields into the surface waters of the Midcontinent.

Precipitation.—The objective of the precipitation reconnaissance was to determine the occurrence and distribution of selected herbicides in atmospheric deposition in 23 Midwest and Northeastern States. Weekly samples of wet atmospheric deposition were collected from 81 National Atmospheric Deposition Program/National Trends Network sites. As a continuation of the herbicides in precipitation project, a study was initiated on the fate of herbicides in precipitation in pristine watersheds. This study is being conducted at Isle Royale National Park, Michigan, which also was a sampling site for the herbicides in precipitation reconnaissance. The objectives of this study are to determine the fate of atmospherically deposited atrazine (a commonly used and detected herbicide) in a watershed where herbicides are not used and to develop analytical methods to measure low-level atrazine concentrations in water and soils.

Ground Water.—The objective of this two-phase reconnaissance was to determine the spatial and seasonal distribution of selected herbicides and nitrate in the near-surface aquifers of the corn- and soybean-producing area of the Midwest. The first phase was a general reconnaissance of 300 wells; the second phase resampled 100 selected wells in order to answer questions about why herbicides were not found where they were expected during sampling in the first phase.

Reservoirs.—The objectives of the Reservoir Reconnaissance are to determine the occurrence, temporal distribution, and persistence of selected herbicides and herbicide metabolites in the outflow from 76 reservoirs in the Midwest and to determine if the persistence of high concentrations of herbicides in reservoir outflow can be attributed to factors associated with reservoir and drainage basin characteristics, land use, herbicide use, and climatic differences.

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Management Systems Evaluation Areas

The Management Systems Evaluation Area (MSEA) Program is part of an interagency initiative to evaluate the effects of agricultural management (farming) systems on water quality. The cooperating agencies of the MSEA Program are the U.S. Department of Agriculture's Agricultural Research Service (ARS) and Cooperative State Research Service (CSRS), the U.S. Environmental Protection Agency, the U.S. Geological Survey, and other Federal and State agencies.

The general goal of the MSEA Program is to reduce the effect of agriculture on the environment through implementation of improved farm management practices. The cooperating agencies of the MSEA Program are collaborating on research at scales ranging from laboratory experiments to small watersheds (about 20 square miles). The objectives of this research are to (1) measure the effects of prevailing and modified farming systems on ground- and surface-water quality, (2) understand the processes and factors affecting the fate of selected agricultural chemicals on ecosystems, (3) assess the effects of selected agricultural chemicals on ecosystems, (4) assess the projected benefits to water quality of implementing modified farming systems, (5) evaluate the socioeconomic impacts of using modified farming systems in the Midwest, and (6) transfer appropriate agricultural technology to farmers.

Five MSEA's were selected to represent the principal hydrogeologic settings and geographic diversity of prevailing farming systems in the Midwest. MSEA's in sand and gravel settings are located in Minnesota, Nebraska, and Ohio; those in loess and till settings are located in Iowa and Missouri. Research focuses on processes that affect ground-water quality at all MSEA's, but processes that affect surface-water quality are also a major consideration at the Iowa and Missouri MSEA's.

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Research on Nonpoint Sources of Ground-Water Contamination in Relation to Land Use

In 1984, under the auspices of the Toxic Substances Hydrology Program, a program was initiated to study nonpoint-source ground-water contamination. The objectives of the program were to investigate the relationship of land use activities to ground-water quality and to test the transferability of these relationships to other areas. The following areas were selected for study:

- Gulf Coastal Plain, Louisiana and Mississippi
- Long Island, New York
- Philadelphia area, Pennsylvania
- Potomac-Raritan-Magothy outcrop area, New Jersey
- Houston area, Texas
- Floridian Aquifer, Florida
- Edwards Aquifer, Texas
- Combined Regolith, North Carolina
- San Joaquin Valley, California
- Arkansas River Valley, Colorado
- Albuquerque-Belen Basin, New Mexico
- High Plains Aquifer, Kansas
- High Plains Aquifer, Nebraska
- Connecticut River Valley, Connecticut

These areas covered a variety of hydrogeologic settings, climates, and land use types; organics and trace metals were the principal contaminants of concern. Seven of these studies (New York, New Jersey, Florida, Colorado, Kansas, Nebraska, Connecticut) were selected for more intensive evaluations. These studies used statistical methods to identify relations between ground-water contamination and land use.

An outgrowth of the New York and the New Jersey studies was a study of nonpoint-source contamination in the Mid-Atlantic coastal plain. The Mid-Atlantic Coastal Plain Study concentrates on the effect of urban, suburban, industrial, and agricultural land use on the occurrence of volatile organic compounds, selected pesticides, metals, and nutrients in ground water. Additionally, the study is trying to correlate and predict the distribution and movement of contaminants in ground water in relation to the patterns of land use.

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Transport of Nonpoint Contaminants in the Cedar River, Iowa

This project describes the movement of selected agricultural chemicals between surface water in the Cedar River and ground water in an adjacent alluvial aquifer in east-central Iowa. The selected chemicals include: nitrate, alachlor, ametryn, atrazine, cyanazine, deethylatrazine, deisopropylatrazine, metolachlor, metribuzin, prometon, prometryn, propazine, simazine, and terbutryn. On a small scale, chemical movements were investigated by installing observation wells in the alluvial aquifer adjacent to the river at an unfarmed site 15 kilometers downstream of Cedar Rapids, Iowa. Ground-water samples from these wells, as well as river and other surface-water samples, were collected during base-flow conditions and selected periods of runoff from May 1989 through July 1991. A two-dimensional ground-water flow model was used to describe quantitatively the movement of bank-storage water into and out of the alluvial aquifer in response to rising and falling river stages. On a large scale, the movement of agricultural chemicals from ground water to surface water was quantified for two periods of time in 1989 and 1990 along a 117-kilometer reach of the Cedar River.

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Agricultural Chemicals in Ground Water Near Plains, Georgia

The objectives of investigations being conducted at a 2-acre research plot near Plains, Georgia, are to study the fate and transport of agricultural chemicals in the unsaturated zone and in ground water and to test the hypothesis that lateral transport can occur in the unsaturated zone. This interdisciplinary study was a cooperative venture of the U.S. Geological Survey, the Agricultural Research Service (U.S. Department of Agriculture), and the U.S. Environmental Protection Agency. Soil data from the research plot where bromide tracer and agricultural chemicals were applied are being used to verify chemical transport and farm management models.

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Program Overview Reports and Review Papers

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This section of the bibliography lists the proceedings from technical meetings conducted under the auspices of the U.S. Geological Survey's Toxic Substances Hydrology Program. These meetings are conducted approximately every 2-1/2 years. Papers are presented at the meetings on research conducted at Toxic Substances Hydrology Program sites and on other research related to toxic substances in the environment. Individual papers from each proceedings are listed in the appropriate section of this bibliography; for example, proceedings papers on the Bemidji, Minnesota, site are listed in the bibliography's section on Bemidji.

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