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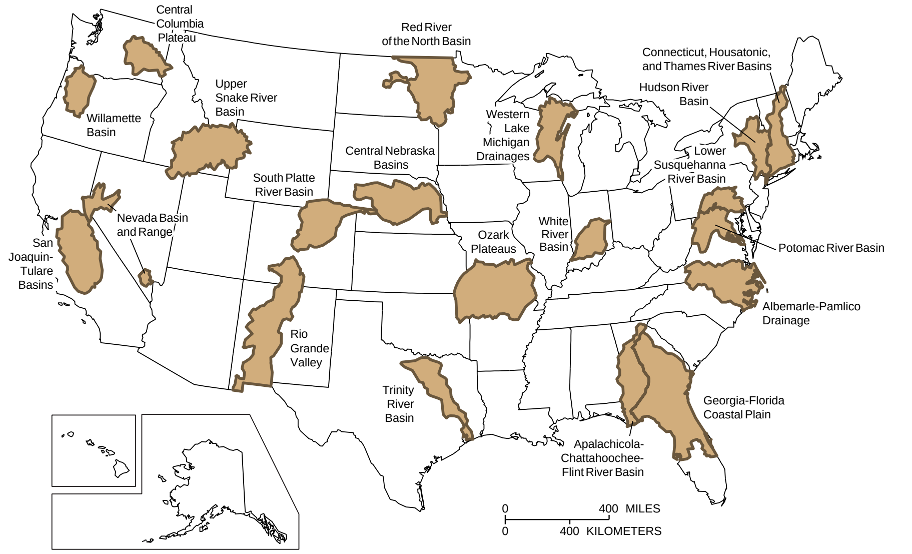
The Quality of Our Nation’s Waters

Nutrients and Pesticides—A Summary

STREAMS AND GROUND WATER in basins with significant agricultural or urban development, or with a mix of these land uses, almost always contain complex mixtures of nutrients (nitrogen and phosphorus compounds) and pesticides. These mixtures are composed of chemicals in current use, others that were used historically (such as DDT, which was banned in the early 1970s), and chemical breakdown products. The types and concentrations of nutrients and pesticides found in streams and ground water are closely linked to land use and the chemicals applied in each setting, such as fertilizers and pesticides applied in agricultural and urban areas, and nutrients from animal and human wastes. Thus, local and regional management of fertilizer and pesticide use can go a long way toward improving water-quality conditions.

Land and chemical use are not, however, the sole predictors of water quality. Concentrations of nutrients and pesticides vary considerably from season to season, as well as among watersheds with differing vulnerability to contamination. Natural features, such as geology and soils, and land-management practices, such as tile drainage and irrigation, can affect the movement of chemicals over land or to aquifers and can thereby exert important local and regional controls on water quality. Understanding the national, regional, and local importance of land and chemical use, natural features, and management practices on water quality increases the effectiveness of policies designed to protect water resources in diverse settings.



National and regional insights on nutrients and pesticides in streams and ground water are based on findings from studies completed in 1998 by the National Water-Quality Assessment (NAWQA) Program in 20 of the Nation’s most important river basins and aquifer systems.

Extent of nutrient contamination and possible concerns

Nitrate, the form of nitrogen most related to human health, generally does not pose a health risk for residents whose drinking water comes from streams or from aquifers buried relatively deep beneath the land. Health risks increase in aquifers located in vulnerable geologic settings, such as in sand, gravel, or karst (weathered carbonate rock), that allow rapid movement of water. In 4 of 33 major drinking-water aquifers sampled, the U.S. Environmental Protection Agency (USEPA) drinking-water standard for nitrate was exceeded in more than 15 percent of samples collected. These aquifers, all of which underlie intensive agricultural areas, are in vulnerable geologic settings in the Central Valley of California, the Great Plains, and parts of the Mid-Atlantic region.

The most prevalent nitrate contamination was detected in shallow ground water (less than 100 feet below land surface) beneath agricultural and urban areas, where about 15 percent of all samples exceeded the USEPA drinking-water standard. This finding raises potential concerns for human health, particularly in rural agricultural areas where shallow ground water is used for domestic water supply. Furthermore, high levels of nitrate in shallow ground water may serve as an early warning of possible future contamination of older underlying ground water, which is a common source for public water supply.

Concentrations of nitrogen and phosphorus commonly exceed levels that can contribute to excessive growth of algae and other nuisance plants in streams. For example, average annual concentra-

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Nutrients and pesticides and their connection to land use

Relative levels of contamination are closely linked to land use and to the amounts and types of chemicals used in each setting. Some of the highest concentrations of nitrogen and herbicides, including those most heavily used (such as atrazine, metolachlor, alachlor, and cyanazine) were detected in samples collected from streams and shallow ground water in agricultural areas. Some of the highest concentrations of phosphorus and insecticides, including those currently used (such as diazinon, carbaryl, and malathion) and those historically used (such as DDT, dieldrin, and chlordane) were detected in samples collected from urban streams.

RELATIVE LEVEL OF CONTAMINATION

	Streams			Shallow Ground Water	
	Urban areas	Agricultural areas	Undeveloped areas	Urban areas	Agricultural areas
Nitrogen	Medium	Medium–High	Low	Medium	High
Phosphorus	Medium–High	Medium–High	Low	Low	Low
Herbicides	Medium	Low–High	No data	Medium	Medium–High
Currently used insecticides	Medium-High	Low–Medium	No data	Low–Medium	Low–Medium
Historically used insecticides	Medium-High	Low–High	Low	Low-High	Low-High

tions of total phosphorus in three-fourths of streams in urban and agricultural areas were greater than the USEPA desired goal for preventing nuisance plant growth, including algae, in streams. Such growth can clog water intake pipes and filters and can interfere with recreational activities, such as fishing, swimming, and boating. In addition, subsequent decay of algae can result in foul odors, bad taste in drinking water, and low dissolved oxygen in aquatic habitats.

Extent of pesticide contamination and possible concerns

The NAWQA Program measured 83 pesticides and breakdown products in water and 32 pesticides in fish or bed sediment. At least one pesticide was found in almost every water and fish sample collected from streams and in more than one-half of shallow wells sampled in agricultural and urban areas. Moreover, individual pesticides seldom occurred alone. Almost every sample from streams and about one-half of samples from wells with a detected pesticide contained two or more pesticides. Although pesticides frequently are found in water, their potential effects on humans and aquatic life are not fully understood. Potential effects must be gauged from a combination of established water-quality standards and guidelines, and by careful consideration of uncertainties and the potential for unaccounted influences due to complexities related to pesticide occurrence.

The good news is that concentrations of individual pesticides in samples from wells and as annual averages in streams were almost always lower than current USEPA drinking-water standards and guidelines. Standards and guidelines have been established for 46 pesticides and breakdown products. Effects of pesticides on aquatic life, however, are a concern based on U.S. and Canadian aquatic-life guidelines, which have been established for 28 of the pesticides measured. More than one-half of agricultural and urban streams sampled had concentrations of at least one pesticide that exceeded a guideline for the protection of aquatic life.

Potential risks to humans and aquatic life implied by NAWQA pesticide findings can be only partially addressed by comparison to established standards and guidelines. Many pesticides and their breakdown products do not have standards or guidelines, and current standards and guidelines do not yet account for exposure to mixtures and seasonal pulses of high concentrations. In addition, potential effects on reproductive, nervous, and immune systems, as well as on chemically sensitive individuals, are not yet well understood. For example, some of the most frequently detected pesticides are suspected endocrine disrupters that have potential to affect reproduction or development of aquatic organisms or wildlife by interfering with natural hormones.

The widespread occurrence of pesticides in water and the pervasive uncertainty in assessing potential effects on humans and aquatic life make pesticide contamination a particularly difficult water-quality problem to resolve. More information is needed on potential effects that are not well understood. In the meantime, our understanding of patterns of pesticide contamination in relation to land use, pesticide use, and the natural characteristics of hydrologic systems can help us to reduce the amounts of pesticides that reach streams and ground water.


Thomas L. Huntzinger

Concentrations of nutrients and pesticides in streams and shallow ground water generally increase with increasing amounts of agricultural and urban land. This pattern is evident within small watersheds, as well as regionally, where similar land-use settings and chemical applications extend over broad areas. For example, intensive herbicide and fertilizer use in the Upper Midwest has resulted in elevated concentrations of atrazine, nitrogen, and phosphorus in streams throughout the region, including the Mississippi River. Management strategies that are successful in reducing use and transport of herbicides and fertilizers could lead to regional improvements in water quality.

Importance of seasonal and geographic patterns in determining protection strategies

Seasonal patterns in water quality of streams emerged in most basins. The patterns reflect many factors, but mainly the timing and amount of chemical use, the frequency and magnitude of runoff from rainstorms or snowmelt, and specific land-management practices, such as irrigation and tile drainage. Concentrations of nutrients and pesticides are highest during runoff following chemical applications. The seasonal nature of these factors dictate the timing of elevated concentrations in drinking-water sources and aquatic habitats.

The geographic distribution of natural features (including topography, geology, soils, hydrology, and climate) and land-management practices (including tile drainage, irrigation, and conservation strategies) also affect the occurrence of nutrients and pesticides in water. These factors make some areas more vulnerable to contamination than other areas, thus, concentrations of nutrients and pesticides can vary among seemingly similar land uses and types of chemical applications.

Ground water is most vulnerable to contamination in well-drained areas with permeable soils that are underlain by sand and gravel or karst. Examples are the Platte River Valley in Colorado and Nebraska, and karst regions within the Susquehanna and Potomac River Basins in Pennsylvania, Maryland, and Virginia. In contrast, streams are most vulnerable in basins with poorly drained clay soils, steep slopes, or limited vegetation to slow runoff. Tile drains and ditches also provide quick pathways for nutrient and pesticide runoff to streams, such as in the White River Basin in Indiana.

Patterns in regional vulnerability are evident where similar natural features, land use, and land-management practices extend over broad areas. For example, ground water underlying intensive agriculture in parts of the Upper Midwest is minimally contaminated where it is protected by relatively impermeable soils and glacial till that cover much of the region. Local hotspots of nitrate and pesticide contamination occur in the region where ancient glacial streams deposited sand and gravel, which enable rapid infiltration and downward movement of water and chemicals. Another example is in the Southeast, where streams and ground water contain relatively low concentrations of nitrogen, partly because soil and hydrologic characteristics in this region favor conversion to nitrogen gas. In contrast, relatively high nitrogen concentrations occur in streams and shallow ground water in the Central Valley of California and parts of the Northwest, Great Plains, and Mid-Atlantic regions, because natural characteristics favor transport of nitrogen.


Peter A. Steeves

Concentrations of nutrients and pesticides generally are higher and more prevalent in streams than in ground water; however, indications of emerging ground-water contamination are important because ground-water contamination is difficult to reverse. Ground-water flow rates are slow, and a contaminated aquifer can take years or even decades to recover.

Water-quality changes

Water quality is constantly changing, from season to season and from year to year. Long-term trends, as captured by the question "Are things getting better or worse?," are sometimes difficult to distinguish from short-term fluctuations. For many chemicals, it is too early to tell whether conditions are better or worse, because historical data are insufficient or too inconsistent to measure trends. Despite these challenges, some trends are evident from monitoring of pesticides and nutrients. These trends show that changes in water quality over time frequently are controlled by factors similar to those that affect geographic variability, including natural features, chemical use, and management practices.

One of the most striking trends is a national reduction in concentrations of organochlorine insecticides, such as DDT, dieldrin, and chlordane, in whole fish. Concentrations of DDT also have decreased in sediment, as indicated in sediment-core samples from urban and agricultural reservoirs and lakes. Just as notable as these declines, however, is that these persistent insecticides still are found at elevated levels in fish and streambed sediment in many urban and agricultural streams across the Nation.

Terry R. Maret

Historical data also show that total nitrogen concentrations have remained stable over the past 20 years in rivers downstream from wastewater treatment plants, such as in the Trinity River in Dallas, Texas. Improved treatment has resulted in decreased concentrations of ammonia and phosphorus despite urban population growth, but has also resulted in changes in the forms of nitrogen in the river. Ammonia is converted to nitrate, which makes the discharge less toxic to fish but may not resolve problems with excessive plant growth.

Kevin F. Dennehy

Changes in concentrations of modern, short-lived pesticides follow changes in use, often focused in specific regions and land-use areas. For example, increases in acetochlor and decreases in alachlor are evident in some streams in the Upper Midwest, where acetochlor partially replaced alachlor for control of weeds in corn and soybeans beginning in 1994. The changes in use are reflected quickly in stream quality, generally within 1 to 2 years.

In contrast, ground-water quality responds more slowly to changes in chemical use or land-management practices, typically lagging by many years and even decades. Local variations in natural features, such as soil types and amounts of recharge, can result in variable rates of ground-water flow, which thereby affect the long-term response to land practices. For example, concentrations of nitrate decreased significantly (from about 18 milligrams per liter in the mid-1980s to less than 2 milligrams per liter in the mid-1990s) in ground water underlying parts of the Central Platte Natural Resources District, Nebraska, after implementation of fertilizer management strategies. Yet, despite implementation of the strategies, the response has been delayed in other parts of the District because of differences in local features controlling ground-water flow. Specifically, concentrations of nitrate remained greater than two times the USEPA drinking-water standard in nearly one-fourth of wells in one area sampled by the District in the mid-1990s.

Science-based lessons for water-quality management and policy

Reductions of nutrient and (or) pesticide concentrations in streams and ground water clearly require management strategies that focus on reducing chemical use and subsequent transport in the hydrologic system. For these strategies to be effective, they should be developed with careful consideration of the patterns and complexities of contaminant occurrence, behavior, and influences on water quality. NAWQA results indicate four basic considerations that are critical for managing and protecting water resources in diverse settings across the Nation.

First, local and regional management strategies are needed to account for geographic patterns in land use, chemical use, and natural factors, which govern hydrologic behavior and vulnerability to contamination. Second, nutrients and pesticides are readily transported among surface water, ground water, and the atmosphere and, therefore, environmental policies that simultaneously address the entire hydrologic system are needed to protect water quality. Third, a top priority should be to reduce the uncertainty in estimates of the risks of pesticides and other contaminants to humans and aquatic life. This will require improved information on the nature of exposure and effects, and development of standards, guidelines, and monitoring programs that address the many complexities in contaminant occurrence. For example, neither current standards and guidelines nor associated monitoring programs, particularly with regard to pesticides, account for contamination that occurs as mixtures of various parent compounds and degradation products, or that is characterized by lengthy periods of low concentrations punctuated by brief, seasonal periods of higher concentrations. Finally, continued development of reliable predictive models is an essential element of cost-effective strategies to anticipate and manage nutrient and pesticide concentrations over a wide range of possible circumstances, over broad regions, and for the long term. An understanding of these considerations will help water managers and policy makers in their implementation of environmental control and protection strategies, in investments in monitoring and science, and in the development of future environmental policies, standards, and guidelines.

This Fact Sheet accompanies a USGS nontechnical publication titled "The Quality of Our Nation's Waters—Nutrients and Pesticides" (USGS Circular 1225). These publications are available through the NAWQA Program. For information, contact:

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