Nutrients in the Nation's Waters: Identifying Problems and Progress

A National Water-Quality Assessment of Nutrients

U.S. Department of the Interior

U.S. Geological Survey

Nutrient pollution is not a new problem, but it is among the most persistent. Consequently, the status of nutrients is one of the first water-quality issues evaluated by the U.S. Geological Survey (USGS) National Water-Quality Assessment (NAWQA) Program.

Public concern about water pollution from nutrients prompted passage of the Clean Water Act in 1972. Yet, more than 20 years later, the U.S. Environmental Protection Agency (USEPA) reports that nutrients are still a water-quality problem—the leading cause of degradation in lakes and estuaries, the third leading cause of impairment in rivers, and the main reason why public supply wells fail to meet USEPA drinking-water standards.

- **When are nutrients a water quality problem?**
- **Do problems exist everywhere or only in certain places?**
- **Are conditions getting better?**

To answer these questions, the NAWQA Program combines the best historical information with new data to arrive at the most comprehensive assessment of nutrients available.

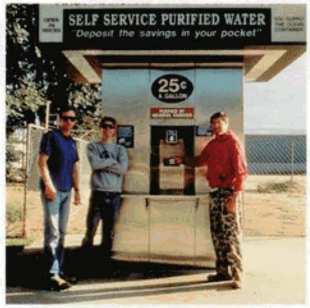
When are nutrients a problem?

All living things need nitrogen and phosphorus, two of the most important nutrients. However, an excess of these nutrients can cause two main types of water-quality problems: degraded aquatic habitat and polluted drinking water. In addition, economic and recreational problems, such as clogged intake pipes and waters that are unfit for swimming, can result.

Scientific guidelines rather than regulatory standards are used to determine when too much nitrate, ammonia or phosphate exists in aquatic habitats. These guidelines reflect the fact that "too much" of any nutrient depends on more than just the amount; water temperature and acidity (pH) are also factors. For example, "maximum exposure criteria" for ammonia, which can be very toxic to fish, range from 0.1 milligrams per liter (mg/L) under some conditions to 2 mg/L under others.

The USEPA enforces a drinking-water standard, or Maximum Contaminant Level (MCL), for nitrate under the Safe Drinking Water Act. If drinking water contains nitrate concentrations in excess of 10 mg/L, it is considered unsafe for human consumption. Indeed, too much nitrate can cause "blue baby syndrome" or methemoglobinemia. This condition can cause death, particularly in infants.

Sometimes, the effects of too much nitrogen or phosphorus in water resources are quite visible: nutrient enrichment triggers a process called eutrophication that is marked by rapid algae growth. Algae grow into "blooms," form scum along the shoreline of lakes, and emit foul odors as plant matter decays. This decay, in turn, depletes dissolved oxygen that fish need to live. Drinking water taken from eutrophic sources may retain foul tastes and odors which, while not necessarily harmful, degrade quality.



Too much nitrate in ground water can render it undrinkable. Near Greeley, Colorado, residents purchase bottled water.

The effects of eutrophication on rivers, streams and lakes may be quite visible. Here, algae form a green scum on the Snake River near Buhl, Idaho.

Ammonia, a form of nitrogen, promotes eutrophication. It dissolves easily in water and can be toxic to fish. It can change into nitrate and ammonia gas.

Nitrate, a form of nitrogen, can harm human health and promote eutrophication. Because it dissolves easily but does not degrade quickly, nitrate can be flushed down to ground water or carried long distances in streams and rivers.

Phosphates, a form of phosphorus, are moderately water-soluble and not very mobile because they adhere to soil particles. Eroded soil carries phosphates to streams and lakes where they can cause eutrophication.

ARE THINGS GETTING BETTER?

Where do nutrients come from?

Natural and anthropogenic (human) sources of nutrients are ubiquitous. In fact, human sources increase as populations increase.

Natural sources of nutrients include soils and decaying plant materials such as fallen leaves and grass. Most nutrients introduced by humans are associated with agricultural and urban settings, and originate in:

- fertilizers and manure used on crops, suburban lawns and golf courses;
- livestock waste from feedlots as well as poultry, hog and dairy farms, and;
- effluent from sewage-treatment facilities.

emissions from power generation and automobiles, lawn fertilizers, and pet waste contain nutrients that can get into water.

The atmosphere is often overlooked as a source of nutrient pollution in water. However, 54 percent of the nitrogen emitted by the burning of fossil fuels (about 3.2 million tons of nitrogen) falls into U.S. watersheds every year.

From watershed to watershed, the main sources of nutrients differ, depending on

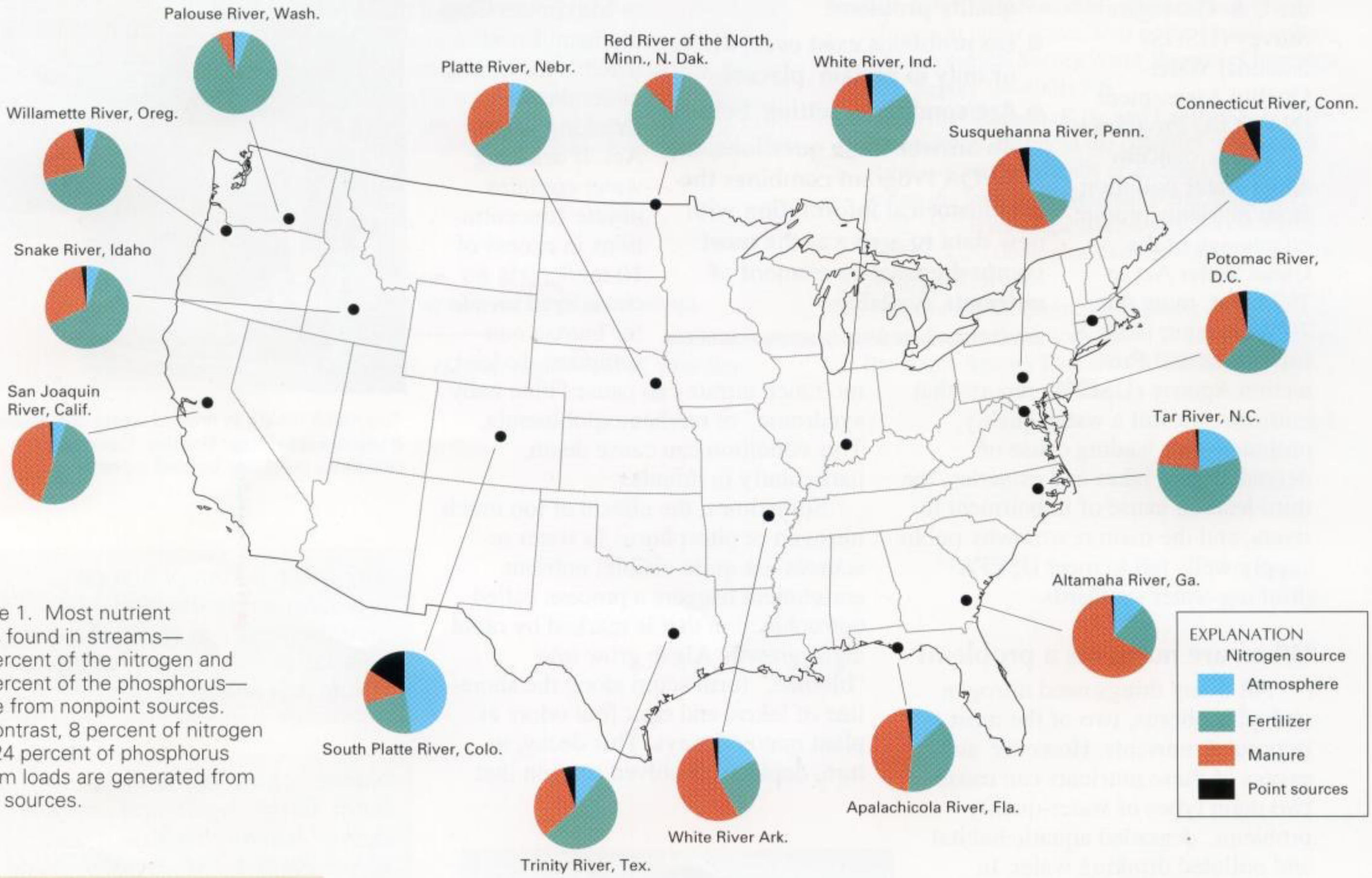


Figure 1. Most nutrient loads found in streams—92 percent of the nitrogen and 76 percent of the phosphorus—come from nonpoint sources. By contrast, 8 percent of nitrogen and 24 percent of phosphorus stream loads are generated from point sources.

"Load" refers to the amount of a nutrient carried by a stream over a period of time (for example, tons of nitrogen per year).

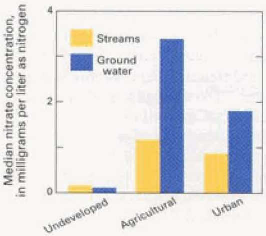
"Point-source" pollution can be traced to specific points of discharge like pipes from waste-treatment plants and factories, confined animal feedlots or combined sewers.

Agriculture covers nearly one-half of the continental United States. This creates widespread opportunities for nutrients that originate on farms to migrate into streams and ground water. Indeed, more nitrogen found in water nationwide comes from agricultural activities than from any other source (fig. 1).

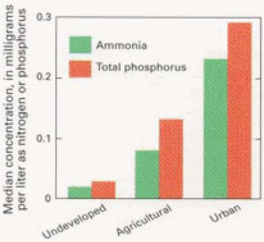
In urban areas, which occupy less than 5 percent of the land base, human sewage, how much land is dedicated to urban, agricultural, forest, or other uses. Because some nutrients can move fairly easily through rivers, on air currents, and in rain, they affect the quality of water not only where they originate, but where they end up in water systems. For example, evidence suggests that nutrients in fertilizer used in Minnesota travel through the Mississippi River as far south as the Gulf of Mexico.

Nutrient levels are highest . . .

The Land Use Connection



Nitrate concentrations are highest in shallow ground water in agricultural areas.



Ammonia and phosphorus concentrations are highest downstream from urban areas.

"Concentration" refers to the amount of a nutrient contained in a certain volume of water (for example, milligrams of nitrate per liter).

. . . in domestic wells that are located in agricultural areas. Fully 12 percent of such wells sampled exceeded the MCL for nitrate. This exceedance rate is two times that of domestic wells in other land use settings, and more than six times higher than the rate of exceedance in public supply wells.

. . . not in public supply wells. Only one percent of public wells exceed the nitrate MCL. Why? Because public supply wells tend to be deep and are less likely to be placed close to cropland and septic systems that increase the risk of nitrate contamination. Also, under the Safe Drinking Water Act, regular monitoring and prompt corrective action is required if public supplies exceed an MCL.

Risk factors for contamination can be identified regionally and, in some cases, locally. Targeted monitoring in watersheds is underway to measure actual concentrations and trends. These methods can also be used for delineation and assessment by States.

. . . in rivers and streams downstream from agricultural and urban areas. Ammonia and phosphorus concentrations are highest downstream from urban areas due to sewage effluent and second highest downstream from agricultural areas, owing to nonpoint runoff. Aquatic ecosystems are very sensitive to nutrients, even at concentrations well below the human drinking-water standard. About 10 percent of samples taken from urban rivers and streams have ammonia levels greater than "chronic exposure criteria" for aquatic life. Phosphorus concentrations exceed in-stream limits recommended by the USEPA in 75 percent of urban streams sampled and 25 percent of agricultural streams sampled.

. . . in the first few weeks of every growing season. Seasonal highs and lows in nitrate concentrations reflect the timing of fertilizer use and the amount of rainfall. For example, nitrate levels in Midwestern streams peak after spring fertilizer applications and heavy rains.

. . . in watersheds at the bottom of regional drainage basins. Nitrogen and phosphorus move across State boundaries in the currents of large rivers. Coastal estuaries and other terminal points in drainage basins may be especially affected by accumulated nutrients.

. . . not in the Southeast, where the large amount of woodland within the agricultural area appears to offset the presence of risk factors for nitrate contamination (fig. 2).

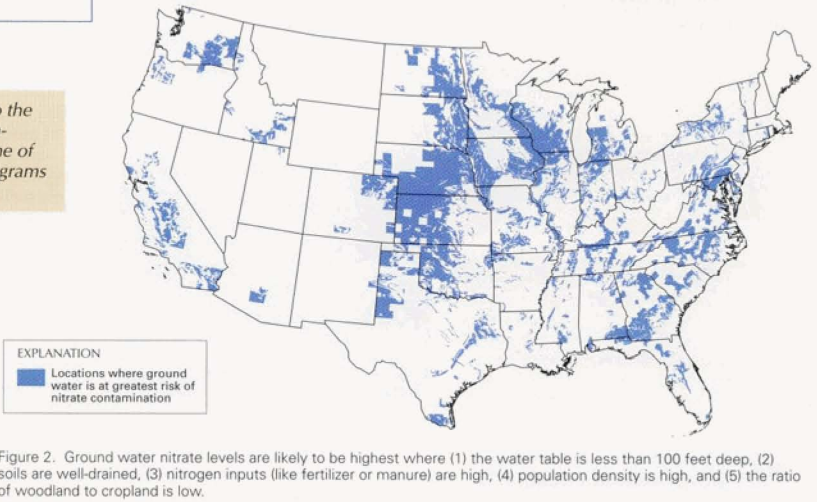


Figure 2. Ground water nitrate levels are likely to be highest where (1) the water table is less than 100 feet deep, (2) soils are well-drained, (3) nitrogen inputs (like fertilizer or manure) are high, (4) population density is high, and (5) the ratio of woodland to cropland is low.

Are conditions getting better?

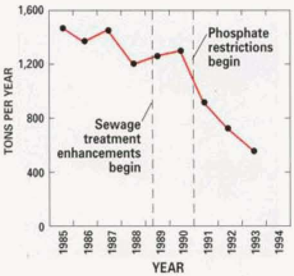


Figure 3. Phosphorus loads in the Chattahoochee River downstream from Atlanta, Georgia, dropped by more than 50 percent after water quality improvement efforts began.

Nationwide, nutrient levels in streams, rivers and ground water changed little between 1980 and 1989—phosphorus levels declined slightly and nitrate levels remained steady. Local trends, which may be more variable, are difficult to assess because historical data are often missing.

Yes. A pattern of declining phosphorus loads in rivers downstream from several urban areas can be explained by restricted use of phosphate in detergents and more effective treatment of waste water. In one case, the amount of phosphorus contained in treated sewage effluent coming from Atlanta, Georgia, dropped by 83 percent in 4 years (1989–93). USGS determined that the amount of phosphorus in the Chattahoochee River fell by 53 percent as a result (fig. 3).

Yes. In Dallas, Texas, and nine other urban areas where enhancements in sewage treatment were begun in the 1970's and 1980's, downstream ammonia concentrations have decreased. These enhancements, which involve transforming ammonia to nitrate, make effluent less toxic to fish, ***but*** may not resolve problems of eutrophication. Why? Because the total amount of nitrogen in the water remains the same, despite the change in form.

Maybe. In several agricultural areas (see inset, right), nitrate levels in streams and rivers generally increased following increases in fertilizer use and decreased following decreases in fertilizer use. Erosion control, reduced tillage practices, nutrient management, and other best management practices (BMPs) can potentially affect water quality. However, it is not clear whether BMPs have overall led to improved water quality.

Channels and pipes used to remove water from fields and pastures also divert nutrients into waterways. Nitrate and phosphates that move downstream can degrade water quality elsewhere in the watershed.

Can't tell yet. Information collected by the USEPA indicates that nitrate contamination causes many "exceedances" (failures to meet a drinking water MCL) in public supply wells. Does this mean ground-water management efforts are not working? Not necessarily. These deep wells may be tapping into "old" water—as much as 50 years old. The benefits of reducing nitrogen use today may not become evident for many years.

Changing Farm Practices, Changing Water Quality

Nitrate concentrations in the lower San Joaquin River have increased since the 1950's. This trend is attributed to concurrent changes in farm practices, such as higher rates of fertilizer application and expanded use of surface drainage, upstream in the watershed.

In the Upper Snake River, a downward trend in phosphorus occurred during the last decade. Upstream, erosion control practices were implemented in agricultural areas during the 1980's. As a result, less phosphorus-carrying sediment has been reaching streams.

Nitrate concentrations in ground water under the Delmarva Peninsula of eastern Maryland mirror changes in fertilizer use. A steep increase in nitrate began in 1968, following a sixfold rise in fertilizer application rates during the preceding two decades. Since 1971, fertilizer use has gradually leveled off and so have nitrate concentrations in ground water.

Evaluation of trends due to changes in farm inputs or practices could not be done at all NAWQA sites because data on water quality both before and after practices changed seldom exists. Because historical data are missing in many locations, data collected by NAWQA forms a baseline for analyzing future trends.

Poultry manure, used as crop fertilizer or stored as waste, can be a source of ammonia and nitrate to ground water and streams.

Where do we go from here?

...with respect to drinking water risks

Recognize that the greatest risk of nitrate contamination exists in shallow household wells in agricultural areas. Such wells may not be monitored regularly since they are not regulated by the Safe Drinking Water Act, and well-owners may not be aware of potential risks posed by adjacent cropland. Where cropland is being rapidly converted to residential developments serviced by household wells, drinking water risks should also be considered. Because nitrate leached to ground water from cropland can be stored for decades, water-quality changes may lag far behind land-use changes.

Where cropland is being converted to residential development, nitrate can be a drinking water concern if domestic wells are expected to be the main water source. (Photograph courtesy of Maguire/Reeder, Ltd.)

...with respect to monitoring

Clarify the relative importance of urban and agricultural sources of nutrients. Available data indicates that agriculture is the source of most of the nutrients introduced into the environment by human activity. However, a full accounting of urban and suburban sources of nutrients—lawns, gardens, golf courses, pet waste, power generation and vehicle emissions—remains incomplete.

Link effluent and ambient monitoring much more closely. To zero in on the scope of remaining point and nonpoint pollution problems, it will be necessary to coordinate point-source effluent monitoring with ambient water-quality monitoring. Neglecting to do so only complicates efforts to pinpoint sources of pollution and to trace improvements from specific efforts.

Pollution from point sources has been addressed, although not resolved, over the past 20 years. But nonpoint sources of pollution—agricultural runoff, drainage from roads and suburban lawns, and pollutants transported by rain and wind—remain significant challenges.

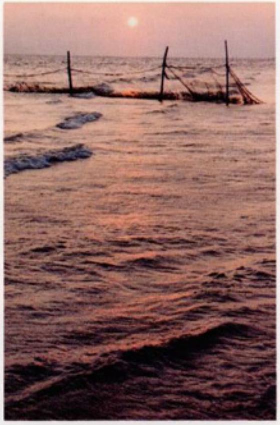
...with respect to watershed management

Take atmospheric sources of nutrients into account. Though atmospheric deposition contributes far less than either urban or agricultural sources of nutrients, it is a significant factor in water quality in the Northeast and the Upper Midwest. However, atmospheric deposition has typically not been factored into watershed protection strategies.

Manage water systems, not water bodies. Surface water, ground water, and the atmosphere are interwoven, although most policies and programs treat them as three separate media. The most effective policies and programs will take such interactions into account.

Consider interstate transport when identifying water-quality priorities. Most of the nitrogen and phosphorus that cross State boundaries is transported through rivers. (For example, about 15 percent, or 1 million tons, of the nitrate contained in fertilizers and manure in the Corn Belt ends up in the Gulf of Mexico each year after a few days journey through the Mississippi River.) Another route is the atmosphere: nitrogen released from the burning of fossil fuels disperses and becomes a nonpoint source of nutrients to surface waters inside and outside the state of origin. Local watershed management efforts may need to coordinate with regional or national efforts when interstate transport is a factor in water quality.

Urban runoff, such as this combined sewer overflow entering Fall Creek in Indianapolis, Indiana, can bring ammonia, nitrate and phosphate into streams.



Ground-water discharge to the Chesapeake Bay equals the amount of water contributed by a major tributary like the James River. Nitrate stored in ground water can enter the Bay in this manner.

About NAWQA

In the mid-1980's, evidence about the status of and trends in the quality of the Nation's water resources remained inconclusive. In response, Congress created the National Water-Quality Assessment (NAWQA) Program, within the U.S. Geological Survey (USGS), to provide sound science about water quality that can be used by local, State, and Federal water managers and policymakers.

The NAWQA Program determines the extent of nutrient and other types of contamination in the Nation's streams and ground water, assesses trends in water quality, and explains the factors that affect water quality. Investigations focus on 59 river basins and aquifer (ground water) systems. Together, these study units cover almost one-half of the country and reflect its diverse land and water resources. Investigations occur in phases, with data collected in 20 units at a time.

One of the initial tasks of NAWQA investigations is to review existing data. By augmenting these data and utilizing innovative investigation methods, the program can make comparisons among regions and trace changes in water quality on a national scale.

For more information contact:
Chief, NAWQA Program
U.S. Geological Survey
413 National Center, Reston, VA 20192
—or go online: http://wwwrvares.er.usgs.gov/nawqa

—by Elisabeth A. Graffy, Dennis R. Helsel, and David K. Mueller

This report is based on:

Battaglin, W.A., Goolsby, D.A., and Coupe, R.H., 1993, Annual use and transport of agricultural chemicals in the Mississippi River, 1991–92, *in* Selected papers on agricultural chemicals in the water resources of the Midcontinental United States: U.S. Geological Survey Open-File Report 93–418, pp. 24–40.

Mueller, D.K., Hamilton, P.A., Helsel, D.R., Hitt, K.J., and Ruddy, B.C., 1995, Nutrients in ground water and surface water of the United States—An analysis of data through 1992: U.S. Geological Survey Water-Resources Investigations Report 95–4031, 74 p.

Mueller, D.K., and Helsel, D.R., 1996, Nutrients in the Nation's water—Too much of a good thing?: U.S. Geological Survey Circular 1136, 24 p.

Puckett, L.J., 1994, Nonpoint and point source of nitrogen in major watersheds of the United States: U.S. Geological Survey Water-Resources Investigations Report 94–4001, 9 p.

Smith, R.A., Alexander, R.B., and Lanfear, K.J., 1993, Stream water quality in the conterminous United States—Status and trends of selected indicators during the 1980's, *in* National Water Summary 1990–91—Hydrologic Events and Stream Water Quality: U.S. Geological Survey Water-Supply Paper 2400, pp. 111–140.

U.S. Environmental Protection Agency, 1995, National Water Quality Inventory, 1994: U.S. Environmental Protection Agency Executive Summary.

October 1996

Fact Sheet FS-218-96

NAWQA Program
U.S. Geological Survey
413 National Center
Reston, VA 20192