

Nitrogen and Phosphorus in Agricultural Streams

Nitrogen is a critical nutrient that is generally used and reused by plants within natural ecosystems, with minimal “leakage” into surface or ground water, where nitrogen concentrations remain very low (Vitousek et al., 2002). When nitrogen is applied to the land in amounts greater than can be incorporated into crops or lost to the atmosphere through volatilization or denitrification, however, nitrogen concentrations in streams can increase. The major sources of excess nitrogen in predominantly agricultural watersheds are fertilizer and animal waste; other sources include septic systems and atmospheric deposition. The total nitrogen concentration in streams consists of nitrate, the most common bioavailable form; organic nitrogen, which is generally less available to biota; and nitrite and ammonium compounds, which are typically present at relatively low levels except in highly polluted situations. Excess nitrate is not toxic to aquatic life, but increased nitrogen may result in overgrowth of algae, which can decrease the dissolved oxygen content of the water, thereby harming or killing fish and other aquatic species (U.S. EPA, 2005). Excess nitrogen also can lead to problems in downstream coastal waters, as discussed further in the [N and P Loads in Large Rivers indicator](#).

Phosphorus also is an essential nutrient for all life forms, but at high concentrations the most biologically active form of phosphorus (orthophosphate) can cause water quality problems by overstimulating the growth of algae. In addition to being visually unappealing and causing tastes and odors in water supplies, excess algal growth can contribute to the loss of oxygen needed by fish and other animals. Elevated levels of phosphorus in streams can result from fertilizer use, animal wastes and wastewater, and the use of phosphate detergents. The fraction of total phosphorus not in the orthophosphate form consists of organic and mineral phosphorus fractions whose bioavailability varies widely.

This indicator reports nitrogen and phosphorus concentrations in stream water samples collected from 1992 to 2001 by the U.S. Geological Survey’s (USGS’s) National Water Quality Assessment (NAWQA) program, which surveys the condition of streams and aquifers in study units throughout the contiguous U.S. Specifically, this indicator reflects the condition of 129 to 133 streams draining watersheds where agriculture is the predominant land use (the exact number of sites with available data depends on the analyte), according to criteria outlined in Mueller and Spahr (2005). These watersheds are located in 36 of the 51 NAWQA study units (i.e., major river basins). Sites were chosen to avoid large point sources of nutrients (e.g., wastewater treatment plants). At each stream site, samples were collected 12 to 25 times each year over a 1-to-3-year period; this indicator is based on a flow-weighted annual average of those samples. Related indicators report the concentrations of [nitrogen and phosphorus in small wadeable streams](#), regardless of land use (in contrast to this more focused indicator), and [nitrate concentrations in ground water in agricultural watersheds](#).

For nitrogen, the indicator reports the percentage of streams with average concentrations of nitrate and total nitrogen in one of five ranges: less than 1 milligram per liter (mg/L); 1-2 mg/L; 2-6 mg/L; 6-10 mg/L; and 10 mg/L or more. This indicator measures nitrate as N, i.e., the fraction of the material that is actually nitrogen. Measurements actually include nitrate plus nitrite, but because concentrations of nitrite are typically insignificant relative to nitrate, this mixture is simply referred to as nitrate. Naturally occurring levels of nitrate and total nitrogen vary substantially across the country, and statistical analyses of water quality data suggest that appropriate reference levels range from 0.12 to 2.2 mg/L total N, such that some streams in the lowest category (less than 1 mg/L) may still exceed recommended water quality criteria (U.S. EPA, 2002).

Concentrations of total phosphorus and orthophosphate (as P) are reported in four ranges: less than 0.1 mg/L, 0.1-0.3 mg/L, 0.3-0.5 mg/L, and 0.5 mg/L or more. There is currently no national water quality criterion for either form to protect surface waters because the effects of phosphorus vary by region and are dependent on physical factors such as the size, hydrology, and depth of rivers and lakes. Nuisance algal growths are not uncommon in rivers and streams below the low reference level (0.1 mg/L) for phosphorus in this indicator, however (Dodds and Welch, 2000), and statistical analyses of water quality data suggest that more appropriate reference levels for total P range from 0.01 to 0.075 mg/L, depending on the ecoregion (U.S.

EPA, 2002). Some streams in the lowest category may exceed these recommended water quality criteria.

What the Data Show

Average flow-weighted nitrate concentrations were 2 mg/L or above in about 60 percent of stream sites in these predominantly agricultural watersheds (Exhibit 1). About 13 percent of stream sites had nitrate concentrations of at least 10 mg/L (the slightly smaller percentage of streams with total N above 10 mg/L is an artifact of the flow-weighting algorithm). Nearly half of the streams sampled had total nitrogen concentrations in the 2-6 mg/L range, and 78 percent had concentrations of 2 mg/L or above.

Nearly half of the streams in agricultural watersheds had average annual flow-weighted concentrations of orthophosphate (as P) of at least 0.1 mg/L (Exhibit 2). Approximately 85 percent of the streams had concentrations of total phosphorus of 0.1 mg/L or above, while 13 percent had at least 0.5 mg/L total phosphorus.

Limitations

- These data represent streams draining agricultural watersheds in 36 of the major river basins (study units) sampled by the NAWQA program in the contiguous U.S. While they were chosen to be representative of agricultural watersheds across the United States, they are the result of a targeted sample design, and may not be an accurate reflection of the distribution of concentrations in all streams in agricultural watersheds in the U.S.
- This indicator does not provide information about trends over time, as the data in Mueller and Spahr (2005) only represent the first cycle of the NAWQA program. NAWQA has completed its second cycle of sampling (2002–2011) and has initiated a third cycle.

Data Sources

Summary data for this indicator were provided by USGS's NAWQA program. These data have been published in Mueller and Spahr (2005), along with the individual sampling results on which the analysis is based.

References

Dodds, W.K., and E. Welch. 2000. Establishing nutrient criteria in streams. *J. No. Am. Benthol. Soc.* 19:186-196.

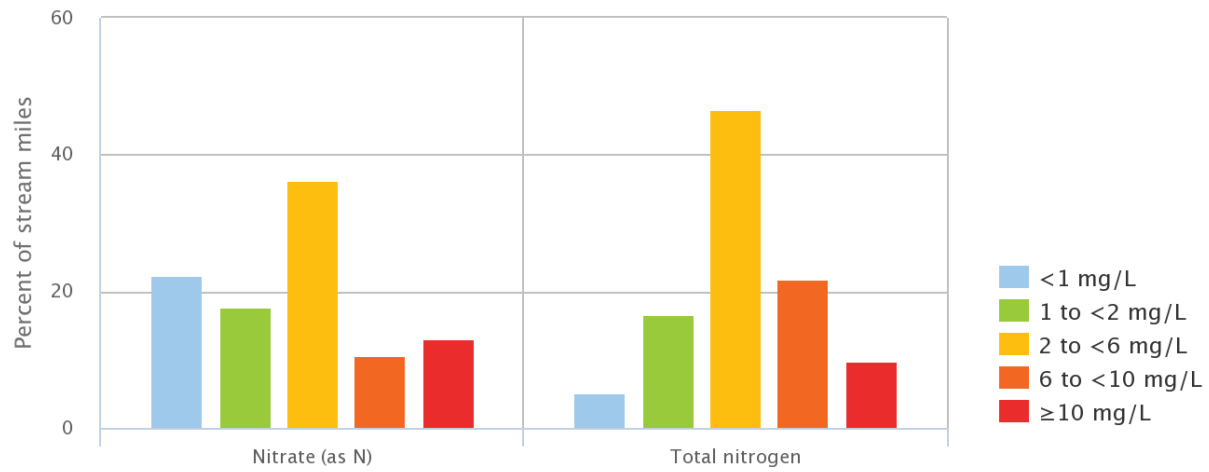
Mueller, D.K., and N.E. Spahr. 2005. Water-quality, streamflow, and ancillary data for nutrients in streams and rivers across the nation, 1992-2001: U.S. Geological Survey data series 152. <http://pubs.usgs.gov/ds/2005/152/>.

U.S. EPA (United States Environmental Protection Agency). 2005. National estuary program—challenges facing our estuaries. Key management issues: Nutrient overloading. <https://www.epa.gov/nep/how-national-estuary-programs-address-environmental-issues>.

U.S. EPA. 2002. Summary table for the nutrient criteria documents. Accessed November 2007. <https://www.epa.gov/sites/production/files/2014-08/documents/criteria-nutrient-ecoregions-sumtable.pdf> (PDF) (3pp, 140K).

Vitousek, P., H. Mooney, L. Olander, and S. Allison. 2002. Nitrogen and nature. *Ambio* 31:97-101.

Exhibit 1. Nitrogen in streams in agricultural watersheds of the contiguous U.S., 1992-2001

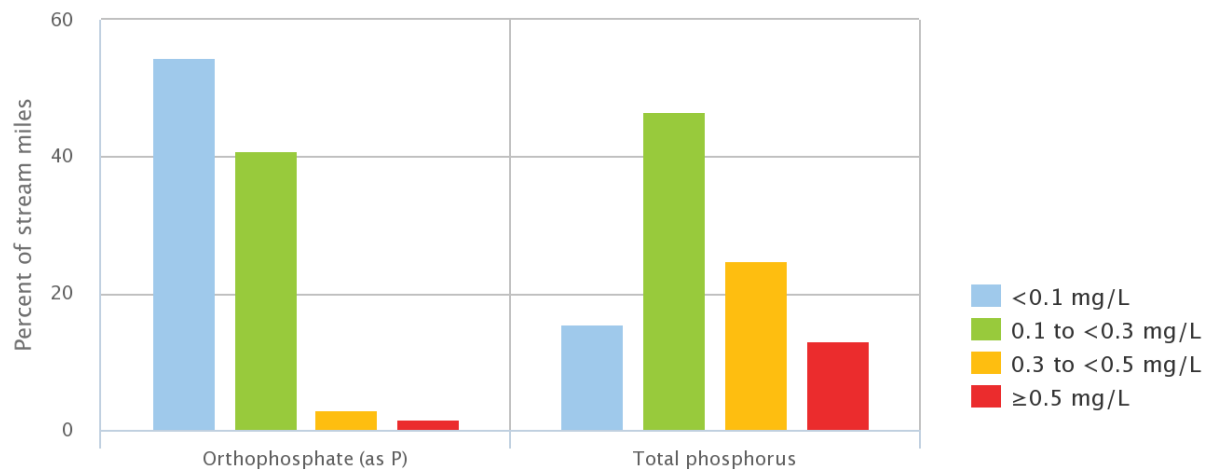


Coverage: Nitrate data from 130 stream sites; total nitrogen data from 133 stream sites. Stream sites are in watersheds where agriculture is the predominant land use. These watersheds are within 36 major river basins studied by the USGS NAWQA program.

Trend analysis has not been conducted because these data represent one cycle of sampling. For more information about uncertainty, variability, and statistical analysis, view the technical documentation for this indicator.

Data source: Mueller and Spahr, 2005

Exhibit 2. Phosphorus in streams in agricultural watersheds of the contiguous U.S., 1992–2001



Coverage: Orthophosphate data from 132 stream sites; total phosphorus data from 129 stream sites. Stream sites are in watersheds where agriculture is the predominant land use. These watersheds are within 36 major river basins studied by the USGS NAWQA program.

Trend analysis has not been conducted because these data represent one cycle of sampling. For more information about uncertainty, variability, and statistical analysis, view the technical documentation for this indicator.

Data source: Mueller and Spahr, 2005