science for a changing world

Nutrients in the Nation's Streams and Groundwater, 1992–2004 – *Implications for human health, aquatic life, and managing nutrients in our water resources*

The U.S. Geological Survey (USGS) has released a comprehensive national analysis of nutrients in streams and groundwater from 1992 through 2004 that describes nutrient occurrence, key sources, natural and human factors affecting concentrations, potential effects on humans and aquatic life, and changes in concentrations. Findings show that nitrate contamination of groundwater used for drinking water, particularly in shallow private wells in agricultural areas, is a continuing human-health concern and that excessive nutrient enrichment is widespread in streams. Despite major Federal, State, and local efforts to control point and non-point sources and transport of nutrients, concentrations of nutrients have remained the same or increased in many streams and aquifers across the Nation since the early 1990s. These USGS findings are relevant to local, State, regional, and national decision-makers involved in efforts to (1) develop nutrient criteria for streams and rivers , (2) reduce nutrients to key estuaries and other receiving waters, (3) track changes in water quality following nutrient reduction strategies, and (4) manage elevated nutrients in drinking water from wells.

Nutrients and potential effects on drinking water and human health

- Contamination by nitrate is a continuing human-health concern in some groundwater used for drinking water, particularly from shallow private wells in agricultural areas. Concentrations exceeded the U.S. Environmental Protection Agency (USEPA) drinking-water standard of 10 milligrams per liter (as nitrogen) in 7 percent of about 2,400 private wells sampled by the USGS. The quality and safety of water from private wells—which are a source of drinking water for about 15 percent of the U.S. population—are not regulated by the Federal Safe Drinking Water Act but are the responsibility of the homeowner.
- Concentrations of nitrate in excess of the drinking-water standard were less common in public-supply wells (about 3 percent), in part because of greater depths, longer travel times, and locations in areas with fewer nutrient sources. Nitrate concentrations are likely to increase, however, in deep aquifers used for drinking-water supplies during the next decade as shallow groundwater with high nitrate concentrations moves downward to deeper aquifers. USGS findings show that the percentage of all sampled wells with nitrate concentrations greater than the USEPA drinking-water standard increased from 16 to 21 percent since the early 1990s. Nitrate can persist in groundwater for years or decades and may continue to be present at high concentrations because of previous land uses and nutrient sources, such as fertilizers, manure, and septic systems.

Nutrients and potential effects on aquatic life in streams

- Recommended nutrient criteria for nitrogen and phosphorus in streams and rivers have been established for different geographic regions of the country by the USEPA to protect beneficial ecological uses and prevent nuisance plant growth. NAWQA results show that measured concentrations of nitrogen and phosphorus were 2 to 10 times greater than USEPA recommended nutrient criteria in most agricultural and urban streams across the Nation. Further reductions in nutrient sources and implementation of water management strategies designed to reduce nutrient transport to streams are needed to meet recommended criteria in most regions.
- Degraded algal communities are associated with increasing nutrient concentrations. The associations were more pronounced for algal communities than for aquatic-insect or fish communities. Inclusion of algal monitoring in Federal and State bio-assessments can serve as an early indicator of stream impairment and may be needed to avoid underestimating water-quality impairment as might be suggested by bio-assessments based only on aquatic-insect and fish communities .

Managing Nutrients in Different Geographic Areas

Understanding fertilizer use and other nutrient sources, as well as natural processes and human factors that control nutrient transport, is needed to effectively manage nutrients in different geographic regions of the country. Such understanding can help decision-makers to anticipate areas that are most vulnerable to nutrient contamination and to identify and set priorities for monitoring and management actions.

- The relative importance of different nutrient sources varies across the Nation and can result in differences in concentrations in streams and groundwater. For example, concentrations of nitrogen generally are highest in agricultural streams in parts of the Midwest, Northern Plains, California Central Valley, and the Northwest, which have some of the most intense applications of fertilizer and manure in the Nation. In contrast, elevated concentrations in many streams in the Northeast and parts of the eastern Midwest are largely influenced by atmospheric deposition.

- Natural features (such as geology, climate, hydrology, and soils) and human activities (such as tile drainage) also result in geographic differences in concentrations in streams and groundwater because they can affect the transport of nutrients from the land to water and thereby make some areas more vulnerable to contamination than others. In addition, natural processes related to geochemical conditions can affect nutrient concentrations. For example, nitrate concentrations are significantly higher in well-oxygenated (or "oxic") groundwater (dissolved oxygen concentration greater than or equal to 0.5. milligrams per liter) than in less oxygenated (or "anoxic") water (concentrations less than 0.5 milligrams per liter), regardless of nitrogen sources. Oxygenated groundwater is most prevalent in geographic settings with well-drained and permeable soils and aquifers with minimal organic matter.

- Specific regional examples showing the role of natural features and processes and human activities:
  - Groundwater in many parts of the upper Midwest contains relatively low concentrations of nitrate, despite intensive agriculture and fertilizer use, because it is protected by relatively impermeable clay soils. Tile drains and artificial subsurface drainage, however, provide quick pathways for nutrients to streams, accentuating elevated nutrient concentrations in streams in this region.
  - Streams and groundwater in the Southeast contain relatively low concentrations of nitrate, in part because soil and hydrologic characteristics—such as poorly drained soils, low dissolved oxygen, and high organic carbon content—favor the conversion of nitrate to nitrogen gases through denitrification. In contrast, well-drained and well-oxygenated soils in the California Central Valley, and parts of the Northwest, Northern Plains, and Mid-Atlantic region favor nitrate persistence and transport into the ground.

- Interactions between groundwater and streams and resulting nutrient exchanges can be substantial across the Nation. At least one-third of the total annual contributions (or "loads") of nitrate in two-thirds of measured small streams was derived from base flow, consisting mostly of groundwater. Groundwater also can contribute significant amounts of dissolved phosphorus to streams, particularly where natural sources of phosphorus are present in the aquifer and where chemical conditions favor phosphorus transport. Determining the contribution of nutrients from groundwater to streams is often not included in estimates of stream loads, but is important for accurate accounting of the relative contributions of point and nonpoint sources in meeting water-quality standards and criteria.

- Groundwater flow can take years or decades to move from the land surface to deeper aquifers. Strategies designed to reduce nutrient inputs on the land will improve the quality of water first in near-surface parts of the water-table aquifer; decades may pass before the quality improves in deeper parts of the aquifer. Similar time delays also are expected for streams that receive considerable groundwater discharge. Long-term systematic and consistent monitoring is essential for evaluating management strategies and for choosing the most-cost effective resource strategies for the future, particularly when evaluating the effectiveness of strategies on groundwater quality.

Contact: Neil Dubrovsky, nmdubrov@usgs.gov, (916) 278-3078