water environment federation

Nutrients: Where and how is Water Quality at Risk?

U.S. Geological Survey
National Water-Quality Assessment Program (NAWQA)

Concerns over contamination of groundwater and streams from nutrients is not new, but it continues to be among the most significant and widespread of the environmental issues faced by government agencies at all levels as well as the private sector. Results from the first phase of NAWQA water-quality assessments provide the following insights on current conditions and trends with respect to nutrients in streams and groundwater, the factors affecting regional patterns and vulnerability of hydrologic systems to nutrient contamination, and implications for environmental management.

- The greatest risks to human health from nitrate contamination exist in shallow household wells in agricultural areas. These wells may not be monitored regularly since they are not regulated under 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.

- Aquatic health-the effects of varying concentrations of nutrients and other factors on algal growth rates in streams is not well understood. Development of this understanding is essential for development of waterbody specific criteria and Total Maximum Daily Loads (TMDL's) for streams with impaired water quality. USGS is working closely with USEPA and other agencies at the national level and with State and local agencies in individual study areas on this issue.

- Watershed management needs to be focused on systems, not individual water bodies. Surface water, ground water and the atmosphere are interwoven, although most policies and programs treat them as three separate systems. The most effective environmental management policies will take such interactions into account. For example, although 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 upper Midwest. Atmospheric deposition typically has not been factored into watershed protection programs. Combined with a water system approach are the complexities of a full accounting of point and non-point sources of nutrients. In this regard, point source effluent monitoring needs to be coordinated with ambient water-quality monitoring. Neglecting to do so complicates efforts to track sources of pollution and to document progress from specific management efforts.

- The significant resources expended to control point source discharges of nutrients from wastewater-treatment facilities have been effective, despite increases in population growth. Nationwide, however, nutrient concentrations in streams and ground water have changed little over the past 20 years. Wastewater treatment generally has reduced concentrations of ammonia nitrogen, which is toxic to fish, but nitrate concentrations have increased in the process and concentrations of total nitrogen and therefore the potential for downstream plant growth (eutrophication) have not changed. Phosphorus concentrations have decreased as a result of reductions in the use of phosphate detergents and in phosphorus discharges from upgraded wastewater treatment plants, but phosphorus levels from all sources combined are still above the USEPA desired goal of 0.1 milligram per liter, which is intended to control algal growth. Trends of nitrate concentrations in ground water are variable and difficult to assess because of the lack of historical data. Case studies show improvements and degradation of ground-water quality in response to changes in cropland management. Because nitrate leached to ground water from cropland can be stored for decades, changes in water quality may lag far behind changes in land use.

Human Health and Aquatic Life

Nitrate concentrations were at safe levels for drinking (less than 10 milligrams per liter) in most streams and major aquifers sampled. The finding that 15 percent of the wells in 4 of 33 major aquifers sampled had concentrations above the drinking water standard is cause for some concern. The most significant nitrate contamination occurred in rural agricultural areas where aquifers are shallow and vulnerable to surface contamination. This is a potential health concern where shallow ground water is used for domestic drinking-water supply. Only one percent of public supply wells exceeded the nitrate drinking-water standard. Why?-because public supply wells tend to be deeper, withdrawing older ground water, and (or) are protected by relatively impermeable geologic materials, such as clay or dense, unfractured rocks.

More than half of all streams sampled had phosphorus concentrations above the USEPA desired goal intended to control algal growth. Nitrogen and phosphorus concentrations in 75 percent of the agricultural and urban streams sampled commonly reached levels that can stimulate excessive growth of algae.

Regional Patterns

Three major factors govern the magnitude and extent of nutrient contamination of streams and aquifers:

Differences in the Sources of Nutrients. On a national scale, agriculture is the largest source of nutrients to the environment. However, effluent from wastewater treatment plants can be an important source of nitrogen and phosphorus in urban streams-particularly during droughts or summer when there is little runoff from rainfall and in population-growth areas of the semiarid areas of the West where effluent may account for a significant proportion of the streamflow year round. Nutrient sources from suburban lawns, gardens, golf courses, pet waste, power generation, and vehicle emissions can also be important, but their relative contribution is difficult to define.

Differences in the Physical Properties of Nitrogen and Phosphorus. NAWQA results show that less than 20 percent of the phosphorus applied to the land is transported to streams. Whereas, up to 50 percent of the nitrogen applied to land is transported to streams. This significant difference is largely due to differences in the physical properties of these two nutrients. Nitrate is readily soluble in water and, thus can more easily wash off the land surface to streams. In contrast, phosphate is less soluble and tends to move with the soil. Many of the current Best Management Practices are designed to reduce soil erosion and, thus also help limit phosphorus transport to streams. These same Best Management Practices would have less effect on the transport of nitrogen to streams.

Regional Differences in Soils, Geology, and Climate. The most vulnerable streams commonly are in basins with relatively:

- High rainfall,
- Poorly drained soils,
- Steep slopes, and
- Limited vegetation to reduce overland runoff

In contrast, the most vulnerable ground water is typically:

- Less than 100 feet below the land surface,
- In areas of high rainfall or irrigation,
- In areas with relatively well-drained soils with low amounts of organic material that are underlain by permeable sand and gravel, fractured rock, or karst, and
- In areas with low slopes.

Implications

Observed patterns of nutrients in the hydrologic environment point to some basic principles for reducing nutrient contamination:

- Reducing use, such as by reducing application rates or improving the efficiency of application or waste treatment, is the surest way to reduce levels of nutrients in water;
- Protection of vulnerable systems is essential. Examples include aquifers in shallow sand and gravel, fractured bedrock, and karst;
- Targeting appropriate Best Management Practices to the most vulnerable environmental settings;
- Recognizing the varying roles of surface water, ground water, and the atmosphere in contributing to contamination issues and accounting for these different roles appropriately in the development of management solutions.