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DEPARTMENT OF THE INTERIOR
BEFORE THE SENATE COMMITTEE ON ENVIRONMENT & PUBLIC WORKS
SUBCOMMITTEE ON WATER AND WILDLIFE
OVERSIGHT HEARING NUTRIENT POLLUTION: AN OVERVIEW OF NUTRIENT REDUCTION APPROACHES
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Chairman Cardin and Members of the Subcommittee, I appreciate the opportunity to appear before the Subcommittee on Water and Wildlife of the Committee on Environment and Public Works with my colleagues from EPA and NRCS to testify on the findings of the U.S. Geological Survey (USGS) studies of nutrients in the Nation's streams and aquifers. I am William H. Werkheiser, Associate Director for Water.

The USGS serves the Nation by providing reliable scientific information to describe and understand the Earth; minimize loss of life and property from natural disasters; manage water, biological, energy and mineral resources; and enhance and protect our quality of life. Monitoring and assessment of water quality conditions in the Nation's streams and aquifers and research on the transport and fate of contaminants in the environment has been a fundamental part of the USGS mission for more than 100 years. Work on nutrients has been a major part of these efforts.

Nutrients are essential for healthy plant and animal populations and provide a range of benefits including increased food production for a growing global population. Too many nutrients, however, are not necessarily a good thing, and can have adverse effects on water quality, drinking water sources, recreation, and aquatic life. For example, excessive nitrate in drinking water can lead to "blue-baby syndrome", or methemoglobinemia, in which oxygen levels in the blood become too low, sometimes with fatal results. Elevated concentrations of nitrogen and phosphorus in streams, lakes, and estuaries can cause excessive growth of algae and other nuisance plants (a condition known as eutrophication). These plants can clog pipes and interfere with recreational activities such as fishing, swimming, and boating. Subsequent decay of algae can result in foul odors and a decrease in the amount of dissolved oxygen in water, also known as hypoxia. Hypoxic conditions, such as those found in the Gulf of Mexico, can harm fish and shellfish that are economically and ecologically important to the Nation. Data submitted by States in 2004, the most recent reporting date to the U.S. Environmental Protection Agency, indicate that 51 percent of the waters they surveyed are too contaminated for basic uses, such as fishing and swimming, because of their nutrient content. The U.S. Geological Survey recently completed a comprehensive national analysis of the distribution and trends of nutrient concentrations in streams and groundwater as part of the National Water Quality Assessment Program (Dubrovsky and others, 2010). The following statement provides an overview of some of the major findings from this analysis.

Occurrence and Distribution of Nutrients in Streams and Groundwater

Streams: Nutrients occur naturally in water, but elevated concentrations usually originate from man-made sources, such as artificial fertilizers, manure, and septic-system effluent. All five nutrients assessed – nitrate, ammonia, total nitrogen, orthophosphate, and total phosphorus – exceeded background concentrations at more than 90 percent of 190 sampled streams draining agricultural and urban watersheds.

Nutrient concentrations in streams are directly related to land use and associated fertilizer applications and human and animal wastes in upstream watersheds. Total nitrogen concentrations were higher in agricultural streams than in streams draining urban, mixed land use, or undeveloped areas, with a median concentration of about 4 mg/L – about 6 times greater than the average concentration of total nitrogen for 89 undeveloped watersheds (0.58 mg/L) sampled across the Nation. Nitrogen concentrations in agricultural streams generally were highest in the Northeast, Midwest, and the Northwest, which have some of the most intense applications of fertilizer and manure in the Nation. Concentrations in parts of the Midwest also are accentuated by artificial subsurface tile drains, which are used to promote rapid dewatering of poorly drained soils. Atmospheric deposition accounts for a significant portion of the nitrogen in streams in some relatively undeveloped watersheds, such as occur in the Northeast. Total nitrogen concentrations were lower in urban streams than in agricultural streams with a median concentration of less than 2 mg/L, but still about 3 times greater than background concentrations. Some of the highest concentrations in urban streams were downstream of wastewater-treatment facilities.

Total phosphorus concentrations were highest in streams in agricultural and urban areas, with a median concentration of about 0.25 mg/L – also about 6 times greater than the average concentration of total phosphorus for undeveloped watersheds that were sampled (0.034 mg/L). (Like nitrogen, high concentrations of phosphorus in agricultural settings are associated with high applications of fertilizers and manure. Urban sources may include treated wastewater effluent and septic-system drainage (in less urbanized settings), as well as runoff from residential lawns, golf courses, and construction sites.

The amounts of nitrogen and phosphorus leaving watersheds in streamflow – referred to as yields (expressed as mass per unit area) – rose with increasing nutrient inputs from nonpoint sources to a watershed, regardless of land use. In addition, 5 to 50 percent of the nitrogen input from nonpoint sources was exported out of most watersheds. Variability in watershed nutrient yields can be explained in part by differences in agricultural practices and in soils, geology, and hydrology. For example, agricultural lands with extensive subsurface tile drains are 3 times more likely to export more than 25 percent of applied nitrogen to streams than agricultural lands with fewer drains. However, less nitrogen is contributed to streams in the Southeast because of greater amounts of denitrification in the soil, as well as in shallow groundwater that ultimately discharges to streams. Less nitrogen also reaches western streams, but for different reasons – generally low amounts of precipitation and runoff, as well as the modification of flow systems by irrigation and impoundments. Phosphorus is less soluble and mobile than nitrogen and thus, phosphorus yields are lower than nitrogen yields for most streams.

Groundwater: Nitrate, the primary nutrient of concern in groundwater, exceeded background concentrations in 64 percent of shallow monitoring wells (depths of less than 100 feet below the land surface) in agricultural and urban areas. Concentrations of other nutrients in groundwater were not significantly greater than background concentrations. Nitrate concentrations in groundwater were highest (median of 3.1 mg/L) in shallow wells in agricultural areas that are associated with high fertilizer and manure applications. Nitrate concentrations were lowest in shallow wells in urban areas (median of 1.4 mg/L), and in deep wells in major aquifers.

The vulnerability of aquifers to nitrate does not depend solely on nutrient sources, but also on groundwater age and geochemical conditions that govern nitrate concentrations in groundwater. Nitrate concentrations were significantly higher in well-oxygenated (or "oxic") groundwater regardless of land use and nitrogen sources. For example, the median nitrate concentration for wells in agricultural areas was 5.5 mg/L in oxic water, but was almost undetectable in less oxygenated (or "reduced") water despite similar nitrogen inputs at the land surface. Nitrate concentrations are especially influenced by the combination of groundwater age and geochemistry; for example, concentrations greater than the U.S. Environmental Protection Agency (USEPA) Maximum Contaminant Level (MCL) of 10 mg/L as nitrogen were never found in groundwater with low dissolved-oxygen concentrations and recharged prior to 1950.

Groundwater contributions of nutrients to streams can be significant – particularly for nitrate. At least one-third of the total annual load of nitrate in two-thirds of 148 small streams studied across the Nation 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 reduced chemical conditions favor phosphorus transport.

There are three important implications from this finding. First, for streams in which groundwater contributions of nutrients are substantial, crop management and irrigation practices, designed to reduce or slow the movement of overland flow to streams, may have only a limited effect on nutrient loads to streams. Second, improvements in water quality as a result of reductions in nutrient inputs on the land may not be apparent in streams for decades because of the slow rate of groundwater movement from the land surface through the subsurface to streams. Third, full accounting and assessment of groundwater contributions of nutrients to surface water is a critical step in developing management strategies to meet water quality goals for protection of drinking water supplies and aquatic life.

Natural processes – including physical, chemical, and biological – can affect exchanges between groundwater and streams. In stream settings containing organic-rich sediments and low dissolved-oxygen concentrations, bacteria convert dissolved nitrate in groundwater to innocuous nitrogen gas through the process of denitrification. These processes are most effective where the geometry of the local aquifer focuses most of the groundwater flow through organic-rich sediments. Nutrients can also be removed by plants in the riparian zone.

Some of the implications of these findings include:

- Nutrient concentrations in streams can be anticipated from information about land use and nutrient sources, along with natural features and management practices that affect the timing and amount of transport of nutrients over land and through the groundwater system.

- Hydrologic settings in which groundwater is least vulnerable to contamination are often those in which streams may be most vulnerable and vice versa. For example, artificial tile drains and ditches often greatly increase the transport of nitrogen from watersheds to streams, but may help protect groundwater from contamination.

Potential for Effects on Human Health

Streams: Nitrate concentrations in streams seldom exceeded the USEPA MCL of 10 mg/L as nitrogen. Nitrate exceeded the MCL in 2 percent of 27,555 samples and in 1 or more samples collected at 10 percent (50 of 499) of the streams assessed. Most streams with concentrations greater than the MCL drained agricultural watersheds and were particularly common in the upper Midwest, where the use of fertilizer and manure is relatively high and tile drains are common. Nearly 30 percent of agricultural streams had one or more samples with a nitrate concentration greater than the MCL, compared to about 5 percent of the streams draining urban land. About 12 percent of public supply intakes on streams are in watersheds draining agricultural areas. None of the samples from streams draining undeveloped watersheds had a concentration greater than the MCL. The implication of this finding is that utilities that withdraw water from streams in undeveloped or mixed land use watersheds, which account for more than 80 percent of the Nation's public-water supply intakes, are unlikely to encounter water with nitrate concentrations greater than the MCL.

Groundwater: Nitrate concentrations greater than the MCL are more prevalent and widespread in groundwater than in streams. Eighty-three percent of studies of shallow groundwater in agricultural areas found at least one sample with a nitrate concentration greater than the MCL (studies generally included 20 to 30 wells). Nationwide, concentrations exceeded the MCL in about 7 percent of 2,388 domestic wells. The quality and safety of water from domestic 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. Elevated concentrations were most common in domestic wells that are shallow (less than 100 feet deep) and located in agricultural areas because of relatively large nitrogen sources, including septic systems, fertilizer use, and livestock. Nitrate can persist in groundwater for years and even decades and may still be present because of previous land uses and management practices. These findings underscore the importance of public education and water-quality testing, particularly for wells associated with current or previously farmed land.

Concentrations exceeding the MCL were less common in public supply wells (about 3 percent of 384 wells). The lower percentage in public wells compared to domestic wells reflects a combination of factors including (1) greater depths and hence age of the groundwater; (2) longer travel times from the surface to the well, allowing denitrification and attenuation during transport; and (3) locations of most public supply wells near urbanized areas where sources of nitrate generally are less prevalent than in agricultural areas.

Even in relatively protected settings, advance planning is required for long-term protection of deep aquifers from nitrate contamination. Groundwater at all depths is part of an integrated flow system and can be vulnerable to future contamination as water moves downward from shallower, contaminated groundwater systems. The potential for future contamination of deep aquifers requires consideration because these aquifers commonly are used as sources of public supply and because restoration of the purity of this relatively inaccessible and slow-moving water is costly and difficult.

Effects on Aquatic Life

USGS findings show the status of streams with respect to region-specific USEPA recommended nutrient criteria, the response of aquatic biota to varying nutrient levels, and the status of streams with respect to USEPA ammonia toxicity criteria. Recommended nutrient criteria for nitrogen and phosphorus in streams and rivers have been established by USEPA for protecting beneficial ecological uses and preventing nuisance plant growth for different geographic regions of the country. USGS results show that measured concentrations of nitrogen and phosphorus were substantially greater than USEPA recommended nutrient criteria in most agricultural and urban streams in most regions across the Nation. Specifically, median concentrations of nitrogen and phosphorus measured at 135 agricultural streams typically were 2 to more than 10 times higher than recommended nutrient criteria. The frequent occurrence of stream nutrient concentrations that are much greater than USEPA recommended nutrient criteria, particularly in streams draining watersheds with significant agricultural and urban development, suggests that substantial reductions in sources of nutrients, as well as increased implementation of land and water management strategies designed to reduce nutrient transport, are needed to meet recommended criteria.

Chlorophyll a, a measure of algal biomass, along with concentrations of nitrogen and phosphorus, is used by USEPA, States, Tribes, and Territories to evaluate nutrient enrichment in streams. Findings suggest that relations between nutrients and chlorophyll a often are weak because other factors, including stream characteristics such as water temperature, flow, and canopy cover, can affect the growth of algal biomass regardless of nutrient concentrations. This results in a relatively wide range of algal response to nutrients in streams even within the same region. In addition, nutrient concentrations in some regions are so much greater than required for plant growth that additional increases in nutrients have little effect on plant biomass. The wide range in biological response to nutrient concentrations supports the need for a regional approach to nutrient criteria and for consideration of local factors related to stream habitat and flow characteristics in the development of these criteria.

Stream ecosystem health can be assessed by measuring the number and types of individuals comprising algal, macroinvertebrate, and fish communities to determine biological condition. Results show that the biological condition of all three communities, expressed as a percentage of the condition expected in minimally disturbed streams, declined with increasing concentrations of nitrogen and phosphorus. Changes were most pronounced for algal communities, in which the average biological condition in streams with elevated nutrients was only about 50 percent, compared to about 80 percent for streams with the lowest nutrient concentrations.

Concentrations of ammonia in streams seldom exceeded the USEPA criteria for protecting aquatic life from ammonia toxicity. Specifically, concentrations exceeded the acute criteria in only 33 samples from 7 streams, out of about 24,000 samples collected from 499 streams. Concentrations exceeded the chronic criteria in 139 samples from 22 sites. The acute and chronic criteria were most often exceeded in streams that drain watersheds with urban and mixed land uses in the semiarid west. Many of these streams also receive treated effluent from wastewater-treatment facilities. Few agricultural sites had concentrations greater than acute (1 site) or chronic (5 sites) criteria, despite relatively large fertilizer and manure sources. More stringent water-quality criteria for ammonia have been proposed by USEPA that could provide greater protection for aquatic life.

Changes in Nutrient Concentrations

Streams: Despite substantial Federal, State, and local efforts to reduce nonpoint-source nutrient loadings to streams and rivers across the Nation, including the Federal Water Quality Initiative from 1990 to 1995, trend analyses for 1993-2003 suggest limited national progress during this period in reducing the impacts of nonpoint sources of nutrients. Instead, nutrient concentrations have remained the same or increased in many streams and aquifers across the Nation and continue to pose risks to aquatic life and human health. These findings are consistent with relatively stable sources of nutrients since the 1980s, including use of fertilizers, applications of manure, and atmospheric deposition of nitrogen.

Sources of nutrients, however, are only one factor that can cause increases or decreases in concentrations. Nutrient concentrations also are influenced by natural variations in precipitation and streamflow, as well as by human activities that affect nutrient transport to streams, such as tile drains, conservation tillage, and other management practices. To focus on trends caused by humans, the USGS trend analysis used “flow-adjusted” nutrient concentrations. Flow adjustment, using long-term records of streamflow, removes variability and trends in concentrations likely caused by natural changes in streamflow. In streams with statistically significant flow-adjusted trends, upward trends were more common than downward trends. Specifically, flow-adjusted concentrations increased at 33 and 21 percent of sites for phosphorus and nitrogen, respectively, and decreased at 16 percent of sites for both nutrients. Increasing nutrient concentrations were most common in relatively pristine streams (those with nutrient concentrations less than USEPA’s recommended regional nutrient criteria). Nearly 40 and 30 percent of these less impacted sites showed upward trends in phosphorus and nitrogen, respectively.

Groundwater: Estimates of groundwater recharge dates – the date when infiltrating water reaches the water table – show that concentrations of nitrate generally have increased since about 1975, consistent with trends in historical fertilizer use in the United States. These findings also are consistent with rates of groundwater flow, which can take years to decades to move water from the water table to a well. Nitrate concentrations were elevated in shallow wells as early as the 1950s and 1960s, whereas concentrations in deep aquifers were not elevated until the 1970s. Nitrate concentrations continued to increase in groundwater over the period 1988 to 2004. Overall, the proportion of 495 wells with concentrations greater than the USEPA MCL of 10 mg/L increased from 16 to 21 percent from the first to the second sampling period. Increases were most common in shallow groundwater beneath agricultural areas. Specifically, median nitrate concentrations increased in the agricultural shallow groundwater from 4.8 to 5.7 mg/L, whereas in deep groundwater in major aquifers, the median nitrate concentration increased from 1.2 to 1.5 mg/L. We expect that nitrate concentrations are likely to increase in aquifers used for drinking-water supplies during the next decade, or longer, as shallow groundwater with high concentrations moves downward into the groundwater system. Improvements in nutrient management practices on the land surface will likely take years to decades to result in lower nutrient concentrations in groundwater because of the slow rate of groundwater flow. Similar time delays also are expected for streams that receive considerable groundwater discharge.

Informing Nutrient Management Decisions

Water resource managers and policy makers have used hydrologic and chemical models to estimate current water-quality conditions for unsampled streams and to predict how conditions might change in response to alternative management actions. However, it's often difficult for decision makers to readily access model information and use models directly to evaluate a range of alternative scenarios. To address this limitation, the USGS has released an online, interactive decision support system that provides easy access to six newly-developed regional models using the SPARROW (SPAtially Referenced Regressions On Watershed attributes) modeling framework describing how rivers receive and transport nutrients from natural and human sources to sensitive waters, such as the Gulf of Mexico. These models were based on monitoring data collected by 73 different organizations from more than 2700 different stream locations that had sufficient data to calibrate the models. Results detailing nutrient conditions in each region are published in the Journal of American Water Resources Association, and can be accessed with the decision support system online.

By making this capability available over the internet in a user interface with familiar controls, modelers and water-resource managers alike can experiment with hypothetical scenarios and develop science-based estimates regarding the effects that specific contaminant sources or changes may have on water quality. These estimates can then be easily communicated to stakeholders and the general public via the same website. Equally important, the decision-support system provides estimates of model uncertainty to inform managers about the range of variability in model predictions of stream loads that can be attributed to uncertainties about how well the models describe actual water-quality conditions and the factors that influence these conditions. The SPARROW decision-support system can be accessed online at water.usgs.gov/nawqa/sparrow/dss.

Thank you, Mr. Chairman, for the opportunity to share USGS research findings on this very important topic. I will be happy to answer any questions you or the other Members may have.

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