IOWA'S WATER
Ambient Monitoring Program

Nitrate Nitrogen in Iowa Rivers: Long-Term Trends

Long–term monitoring is essential for identifying trends in water quality, for understanding how society's activities impact water quality, and for making informed decisions regarding management of our water resources. We lack long-term and historical water quality data for most Iowa rivers, and for most water quality parameters. However, such information is available for nitrate-nitrogen (nitrate-N) concentrations from the Iowa, Cedar and Des Moines rivers (Figure 1).

Nitrate-N concentrations have increased in Iowa's major rivers in the last half-century.

Nitrate-N is the most common form of nitrogen in Iowa's rivers, streams and groundwater. Excess concentrations in streams may lead to algal blooms and eutrophication, conditions which can affect aquatic life locally as well as downstream. Nitrate-N is also the most common form of nitrogen carried to the Gulf of Mexico by the Mississippi River. An increased delivery of nitrogen and other nutrients by the Mississippi appears to contribute to *hypoxic,* or low-oxygen, conditions in the Gulf, which in turn affect aquatic life. Nitrate-N concentrations in excess of 10 mg/L in drinking water may cause *methemoglobinemia* or "blue baby" syndrome in infants, and there are other potential health concerns with nitrate-N in drinking water. Therefore, the U.S. Environmental Protection Agency has set the maximum contaminant level for nitrate-N at 10 mg/L.

Nitrate-N in streams originates from a variety of sources. Agricultural sources include nitrogen fertilizer, animal manure, mineralization of soil nitrogen, and nitrogen-fixing

Figure 1. *Map showing the Des Moines, Iowa and Cedar River watersheds.*

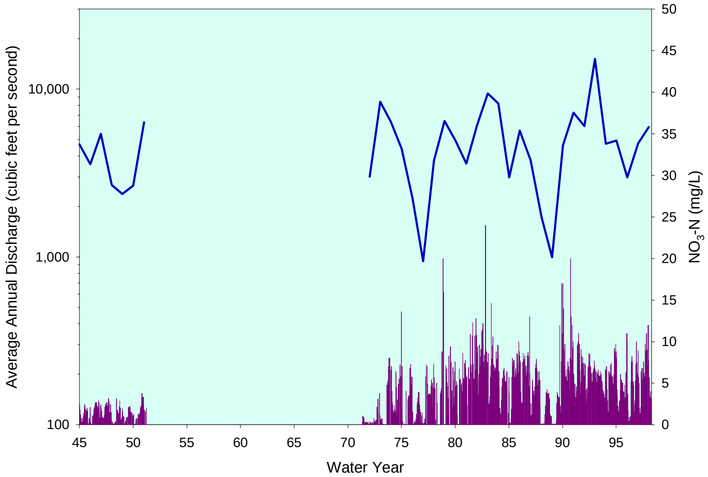

Figure 2. *Nitrate-N concentrations (purple bars) and average annual discharge (blue line) for the Cedar River near Cedar Rapids.*

crops. Other sources include human waste from sewage treatment plants, septic systems and landfills, and nitrogen produced as a waste or by-product of some industrial processes. Rainfall also contributes some nitrate-N. In a largely agricultural state such as Iowa, agricultural sources predominate. Nitrate-N concentrations are typically higher in more intensively row-cropped watersheds. Conversely, concentrations show no relationship to watershed population or population density, another measure for non-agricultural nitrate-N sources.

Data from the Iowa, Cedar and Des Moines rivers show that nitrate-N concentrations have increased significantly over the past half-century. Figure 2 shows nitrate-N concentrations in the Cedar River near Cedar Rapids. Samples have been routinely collected since the early 1970s. Samples were also collected during the 1945-1951 period. Sample collection intervals were typically biweekly. Also shown is the average annual discharge, or flow rate, for the Cedar River during these years. The discharge is included because previous investigations have shown that nitrate concentrations in streams are typically higher in wetter years with higher stream flows. The graph clearly shows that nitrate-N concentrations have been considerably higher in the last 20 years than they were during the 1945-1951 period. Comparing the averaged individual sample results from the two periods suggests concentrations have increased several-fold. In addition, stream flows during 1945-1951 appear generally similar to those of the last 30 years. This suggests the increased concentrations of nitrate-N are not from wetter climatic conditions and the resulting higher stream flows.

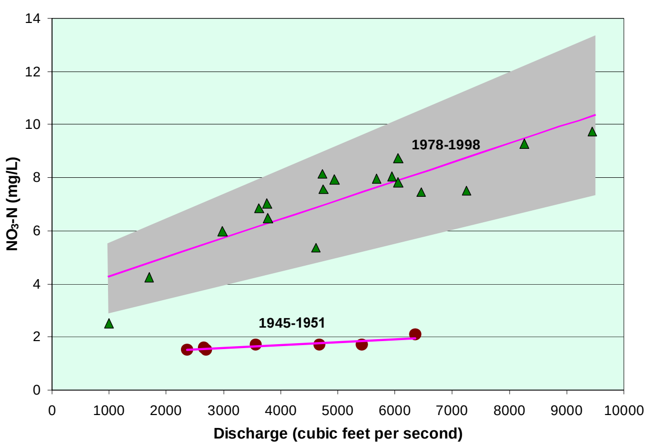

Figure 3. *Comparison of the relationship between average annual nitrate-N concentrations and discharge for 1945-1951 versus 1978-1998.*

While the monitoring record shows concentrations have increased, quantifying the increase involves more than averaging the individual sample results. Nitrate-N concentrations may vary daily as stream flows change, and the relationship between

Nitrate-N concentrations can vary daily with changes in streamflow, and are typically lower in streams draining less-intensively row-cropped watersheds.

concentration and flow may be affected by seasonal and other factors. So in order to more clearly assess the amount that nitrate-N concentrations have increased, the individual sample results were used to estimate annual average concentrations. Three different methods, all of which utilize the relationships between stream flow, nitrate-N concentrations and other variables, were used for this estimation. A statistical relationship between the resulting average annual nitrate-N concentrations and average annual stream flows could then be established for each time period. These can then be compared to assess how annual average nitrate-N concentrations have changed under comparable annual flow conditions.

Figure 3 is a graphical example of this process for the Cedar River. The heavy lines drawn through the points are statistical "best fits" to the concentration-discharge rate relationships for each period. The shaded area around the 1978-1998 data represents the statistical 95% confidence level associated with the best-fit line. The data points and best-fit line from 1945-1951 fall below this area, indicating that there has indeed been a statistically significant increase in nitrate-N concentrations.

How much have concentrations increased since the 1945-1951 period? As Figure 3 shows, the increase depends upon what stream flow condition one wants to compare. The long-term average discharge for the Cedar River is about 3,800 cubic feet/second. At this average rate, concentrations in the 1940s would have averaged a little less than 2 mg/L. In recent years, concentrations have been about 6 mg/L, indicating a three-fold increase under average discharge conditions. Data for the Iowa River show a similar increase. For the Des Moines River, the historical record consists of only one year, 1945. When flow rates in recent years were similar to those of 1945, average nitrate-N concentrations for

The nitrate-N in Iowa streams is delivered to the Mississippi River and ultimately to the Gulf of Mexico.

the Des Moines were 75 to 100% higher than in 1945.

The data from 1978-1998 show a typical increase in average nitrate-N concentrations with increased discharge (Figure 3). This relationship is indicative of widespread non-point sources of nitrate-N, which can interact with large volumes of water falling as rain and feeding stream flow. In contrast, many point sources of nitrate-N, such as septic systems and wastewater facilities, supply a relatively constant load of nitrate-N to the environment, one that doesn't increase because of wetter years. Interestingly, data from 1945-1951 show very little increase in concentration with discharge. This may have resulted from a lesser contribution from nonpoint nitrate-N sources, relative to point sources, fifty years ago.

Measuring changes in water quality is only possible with the results of consistent, long-term monitoring. A similar effort is needed to document changes in land use, cropping systems, fertilizer inputs, waste treatment and other factors that may account for the observed changes. Understanding coincident changes in water quality and land use in the past is essential to creating water-quality improvements for the future.

Acknowledgements

Nitrate-N monitoring data are from the Department of Civil and Environmenal Engineering at the University of Iowa and the Department of Civil and Construction Engineering at Iowa State University, with funding from the Duane Arnold Energy Center and the U.S. Army Corps of Engineers. River discharge data is from the Iowa District office of the U.S. Geological Survey.

Funding

Water monitoring activities of the Iowa Department of Natural Resources are funded by Iowa Infrastructure and State General Fund appropriations, as well as grants provided by the U.S. Environmental Protection Agency from Sections 106 and 319 of the Clean Water Act.

Prepared by
Iowa Department of Natural Resources, Geological Survey Bureau
109 Trowbridge Hall, Iowa City, IA 52242-1319

Photos by Gary Hightshoe, Iowa State University