Nutrient Sources Within the Upper Mississippi River Basin, Minnesota and Wisconsin, 1991-93

The amount of nutrients contained in fertilizer, livestock manure, municipal wastewater, atmospheric deposition, and legume residues were quantified in each of the major drainage basins within the Upper Mississippi River Basin study unit (fig. 1) as part of the U.S. Geological Survey’s National Water-Quality Assessment Program. These sources of nutrients may potentially affect surface- and ground-water quality, so knowledge about the relative importance of each source may assist in the management of surface and ground waters within the study unit. The relative importance of each nutrient source was expected to vary among each of the four drainage basins due to differences in land use across the study unit.

Fertilizer and livestock manure were potentially large sources of nitrogen and phosphorus in each of the four drainage basins. However, nitrogen in legume residues was a more important source in the Upper Mississippi, St. Croix, and Lower Mississippi River Basins because hay comprised a larger part of the total acreage of crops grown in these basins. Atmospheric deposition comprised a larger percentage of the nitrogen sources in the St. Croix River Basin compared to the other three drainage basins probably because amounts of the other sources are relatively low. Nitrogen and phosphorus yields in streams were greatest in the Lower Mississippi River Basin and the Minnesota River Basin, where amounts of nonpoint sources of these constituents also were the greatest per square mile.

Introduction

In 1994, the U.S. Geological Survey began studies in the Upper Mississippi River Basin as part of the National Water-Quality Assessment Program. The purpose of the program is to
The Upper Mississippi River Basin study unit (fig. 1) encompasses an area of about 47,000 square miles and includes the drainage area of the Mississippi River from the source to the outlet of Lake Pepin, a natural lake on the river, and its two principal tributaries—the Minnesota and St. Croix Rivers. The seven-county Twin Cities (Minneapolis and St. Paul) metropolitan area (TCMA) is located in the southeastern part of the study unit.

There are four major drainage basins in the study unit—Upper Mississippi, Lower Mississippi, St. Croix, and Minnesota River Basins. In this paper, the Upper Mississippi River Basin (UMRB) is defined as the entire drainage of the Mississippi River upstream of Anoka, Minnesota, and the Lower Mississippi River Basin (LMRB) is defined as the drainage of the Mississippi River from Anoka, Minnesota to the outlet of Lake Pepin (excluding the drainage areas of the Minnesota and St. Croix Rivers).

Land use varies among these four drainage basins. The Minnesota River Basin (MRB) consists primarily of agricultural land. Soybeans and corn are the principal crops grown, and pigs are the dominant type of livestock raised in this basin. Data obtained from the state agricultural censuses (Iowa State University, 1994; Minnesota Agricultural Statistics Service, 1995; North Dakota Agricultural Statistics Service, 1994; South Dakota Agricultural Statistics Service, 1994) showed that the MRB produced approximately 75 percent of the soybeans and 65 percent of the corn and pigs raised in the study unit in 1993.

Land use in the UMRB is primarily a mixture of agriculture and forest. The major crops grown in this drainage basin are hay and corn. The predominant livestock raised in the UMRB are dairy cows, beef cows, and pigs. Data obtained from the state agricultural censuses (Minnesota Agricultural Statistics Service, 1995; Wisconsin Agricultural Statistics Service, 1994) showed over half of the hay grown in the study unit in 1993 was from the UMRB. About half of the milk cows, 45 percent of the beef cows, and about 20 percent of the pigs raised in the study unit in 1993 also were from the UMRB.

The LMRB consists primarily of agricultural land and also includes the TCMA. The major crops grown in this drainage basin are corn, soybeans, and hay. The major livestock raised are pigs and cattle. Data obtained from the state agricultural censuses (Minnesota Agricultural Statistics Service, 1995; Wisconsin Agricultural Statistics Service, 1994) showed that about 10 percent of the corn, soybeans, hay, pigs, beef cows, and milk cows raised in the study unit in 1993 were from the LMRB.

The St. Croix River Basin (SCRB) consists predominantly of forested and agricultural land. The major crops produced in this drainage basin are hay and corn. The major livestock raised in the SCRB are cattle. Data obtained from the state agricultural censuses (Minnesota Agricultural Statistics Service, 1995; Wisconsin Agricultural Statistics Service, 1994) showed about 20 percent of the hay and less than 5 percent of the corn produced in the study unit in 1993 was from the SCRB. In 1993, about 15 percent of the milk cows and beef cows in the study unit also were raised in the SCRB.
Andrews (1997). For the LMRB, the amount of nitrogen and phosphorus contained in each source was obtained by difference.

Approximately 760,000 tons of nitrogen and 132,000 tons of phosphorus from fertilizer, livestock manure, municipal wastewater, atmospheric deposition, and legume residues have the potential to affect water quality in the study unit each year (fig. 2). Most of the nitrogen and phosphorus from these sources in the study unit are from the MRB and the UMRB (fig. 2). However, these are the largest of the four drainage basins. Greater amounts of nutrients per unit area may increase the likelihood of transport to surface or ground water. On a per-square-mile basis, most of the nitrogen and phosphorus from the five sources quantified in this analysis (table 1) was to the MRB and LMRB.

Table 1. Amounts of nitrogen and phosphorus in the Upper Mississippi River Basin study unit that may potentially affect water quality, 1991-93, by drainage basin

<table>
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<tr>
<th>Drainage basin</th>
<th>Nitrogen</th>
<th>Phosphorus</th>
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<tbody>
<tr>
<td>Minnesota River</td>
<td>23</td>
<td>4.6</td>
</tr>
<tr>
<td>Upper Mississippi River</td>
<td>12</td>
<td>1.8</td>
</tr>
<tr>
<td>St. Croix River</td>
<td>8</td>
<td>0.9</td>
</tr>
<tr>
<td>Lower Mississippi River</td>
<td>24</td>
<td>4.1</td>
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</table>

Fertilizer and livestock manure were the predominant sources of nitrogen and phosphorus to each of the drainage basins (figs. 3 and 4). These sources comprised from 57 to 83 percent of the nitrogen sources and from 91 to 99 percent of the phosphorus sources in each of the four drainage basins. The relative importance of the other sources of nitrogen in the study unit varied among each of the drainage basins. Nitrogen in legume residues was a more important source in the UMRB, SCRB, and LMRB relative to the MRB because hay comprises a larger part of the total acreage of crops grown these drainage basins. Atmospheric deposition is a more important source of nitrogen in the SCRBB compared to most of the other sources probably because inputs from fertilizer, manure, and legume residues in this basin are relatively low. Municipal wastewater discharges comprise a larger nitrogen and phosphorus source in the LMRB relative to the other drainage basins because of direct discharges to the Mississippi River from the TCMA.

There were greater amounts of fertilizer and livestock manure applications per square mile in the MRB and LMRB relative to the UMRB and SCRB (table 2). However, the amounts of fertilizer and livestock manure applied in each drainage basin is not uniform. For example, in the UMRB more fertilizer and manure is probably applied in the southern and western parts where agri-
Table 2. Amounts of nitrogen and phosphorus in fertilizer, livestock manure, legume residues, atmospheric deposition, municipal wastewater, and streams in the Upper Mississippi River Basin study unit, 1991-93, by drainage basin

<table>
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<tbody>
<tr>
<td>Minnesota River</td>
<td>14 (2.40)</td>
<td>5.18 (2.11)</td>
<td>1.88</td>
<td>1.96</td>
<td>0.16 (0.07)</td>
<td>6.1 (0.22)</td>
</tr>
<tr>
<td>Upper Mississippi River</td>
<td>4.8 (0.85)</td>
<td>3.13 (0.88)</td>
<td>2.17</td>
<td>1.65</td>
<td>0.05 (0.02)</td>
<td>3.87 (0.07)</td>
</tr>
<tr>
<td>St. Croix River</td>
<td>2.5 (0.45)</td>
<td>2.09 (0.45)</td>
<td>1.50</td>
<td>1.99</td>
<td>0.02 (0.007)</td>
<td>0.78 (0.03)</td>
</tr>
<tr>
<td>Lower Mississippi River</td>
<td>11 (1.93)</td>
<td>5.42 (1.80)</td>
<td>4.14</td>
<td>2.20 (0.37)</td>
<td>8.08 (0.33)b</td>
<td></td>
</tr>
</tbody>
</table>

¹Fertilizer year 1991 (July 1, 1990 to June 30, 1991) estimate
²Average of yields in Vermillion and Straight Rivers, major tributaries

Cultural land use is more concentrated (fig. 1). More nitrogen is available per square mile from legume residues in the LMRB (table 2) because almost half of the crops grown in this basin in 1993 were hay and soybeans.

**Implications to Water Quality**

This analysis illustrates the importance of nonpoint sources of nitrogen and phosphorus, especially fertilizer and livestock manure, to the major drainage basins of the study unit. Nitrogen and phosphorus yields in streams were greatest in the MRB and LMRB, where amounts of nonpoint sources of these constituents also were the greatest per square mile (table 2). Nitrogen and phosphorus from nonpoint sources generally are transported to streams by runoff. However, point sources, which generally discharge directly to streams in the study unit (Kroening and Andrews, 1997), may be important local sources of nutrients in the study unit.

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**References**

Iowa State University, 1994, Iowa agricultural statistics: Iowa State University, Ames, Iowa, 112 p.


