91-235

WATER FACT SHEET

U.S. GEOLOGICAL SURVEY, DEPARTMENT OF THE INTERIOR

RELATION OF NITRATE CONCENTRATIONS IN WATER TO AGRICULTURAL LAND USE AND SOIL TYPE IN DAKOTA COUNTY, MINNESOTA, 1990

INTRODUCTION

The quality of surface and ground water can be related to various physical factors such as land use, soil type, geology, and depth to water table. Land use in Dakota County, Minnesota, is changing: urbanization and industrialization in the north and increasing irrigation and application of agricultural chemicals in the central part of the county. The U.S. Geological Survey, in cooperation with the Minnesota Department of Natural Resources, the Legislative Commission on Minnesota Resources, and the Dakota County Soil and Water Conservation District, is studying the relations between some physical factors and the quality of surface-and ground-water in Dakota County. The findings of the study can be used by local officials involved in land-use planning and management.

Nitrate is commonly found in ground water in agricultural areas throughout the Midwest. The emphasis of this report is to relate differences in nitrate concentrations in ground water to agricultural land use and soil type. In addition, nitrate concentrations in streams, shallow ground water near the water table, and deeper ground water from 10 to 30 feet below the water table are tabulated for selected sites in Dakota County.

Setting

Dakota County is immediately to the southeast of the Minneapolis-St. Paul area (fig. 1). The high permeability of sand deposits that cover much of the county permits water and dissolved chemicals to percolate rapidly through the unsaturated zone to the water table. The sand in the northern part of the county is commonly interbedded with finer grained, less permeable glacial till; the sand in the central part of the county is more homogeneous and can be more than 100 feet thick.

The drainage basin of the Vermillion River is almost entirely within Dakota County and covers about 215 square miles total (fig. 1). The river flows generally eastward through the central part of the county and joins the Mississippi River, which forms the northeastern border of the county. The median discharge of the Vermillion River near its mouth was about 70 cubic feet per second during 1990. Overland runoff contributes to streamflow during spring snowmelt and some storms; at these times discharge can exceed 1,500 cubic feet per second. Much of the streamflow, however, originates from ground-water seepage into the stream in the upstream and central parts of the basin. A typical flow path for precipitation falling on the Vermillion River basin would be to percolate through the unsaturated sands to the water table, at which point the ground water would move mostly horizontally toward streams or rivers. Along some reaches of the Vermillion River, however, water infiltrates from the river into the aquifer.

Data Collection

Two study sites were established along the main stem and three sites were established along tributaries of the Vermillion River to characterize variability in nitrate concentrations over time and to determine the connection between ground water and surface water (fig. 1). At site 5, the channel of the Vermillion River is about 40 feet above the water table, and a single well was completed to the approximate depth of the water table. At each of the other four sites, two wells were completed, one to a depth near the water table and the other to a depth 10 to 30 feet below the water table in the unconsolidated surficial aquifer. Water levels in these wells were used to determine whether the river was gaining or losing water through the aquifer. Surface water and ground water at each site were sampled 9 or 10 times during March-September 1990.

Water samples collected from 20 domestic wells in northern and central Dakota County during September 1990 (fig. 1) were analyzed to determine the relation of nitrate concentration in ground water to agricultural land use and soil type. The percentage of areal coverage of agricultural land use within 0.62 mile of each well was calculated, and the soil type at each well was characterized by the potential for agricultural chemicals to leach through the topmost 60 inches of the unsaturated zone.

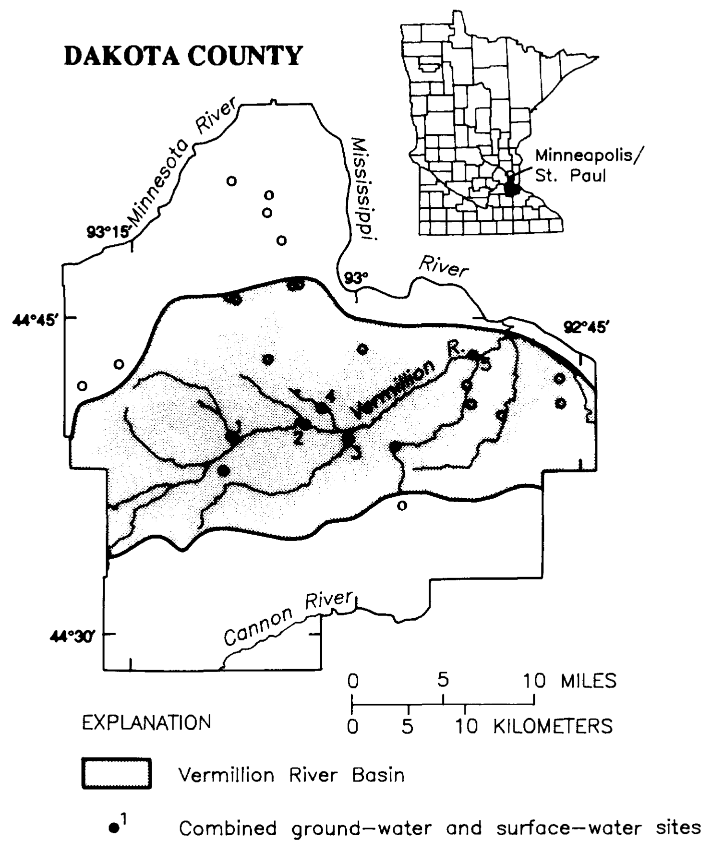

Figure 1. *Location of Vermillion River basin, Dakota County, Minnesota, and sampling sites for determination of nitrate concentrations in surface water and ground water.*

NITRATE CONCENTRATIONS IN DAKOTA COUNTY SURFACE AND GROUND WATER

Median concentrations of nitrate at the five combined surface-water/ground-water sites along the Vermillion River basin (fig. 1) generally were similar for both surface water and shallow ground water near the water table. Median concentrations ranged from 0.4 to 8.4 milligrams per liter nitrate nitrogen (table 1). Nitrate concentrations generally were lower for the deeper ground water 10 to 30 feet below the water table (usually less than 0.1 milligrams per liter nitrate nitrogen).

A full characterization of the nitrate concentrations of surface water or ground water from a site requires an assessment of variability with time. Nitrate concentrations varied the most at shallow ground-water sites, as shown by the large ranges of values (the differences between the maximum and minimum values, table 1). Nitrate concentrations varied the least at the deeper ground-water sites. Nitrate concentrations varied an intermediate amount for surface water, which includes a mixture of shallow and deeper ground water as well as some overland runoff.

Table 1. ***Nitrate concentrations from five sites along the main stem and tributaries of the Vermillion River, Dakota County, Minnesota, from March to September 1990***

[min, minimum; med, median; and max, maximum; in milligrams per liter nitrate-nitrogen. n, number of samples. Flow is in cubic feet per second and corresponds to those specific sampling times yielding the min or max nitrate concentrations. <, less than. NA, not available.]

	Stream water				Shallow ground water				Deeper ground water			
	min (flow)	med	max (flow)	n	min	med	max	n	min	med	max	n
Site 1 tributary	0.5 (3.9)	0.9	4.0 (33.9)	7	0.1	0.4	1.6	10	<0.1	<0.1	<0.1	10
Site 2 main stem	3.1 (149)	5.0	6.5 (19.1)	8	6.5	8.4	16.0	9	<.1	<.1	<.1	10
Site 3 tributary	2.7 (37.4)	4.9	5.9 (5.9)	9	2.1	4.5	11.0	9	<.1	<.1	<.1	9
Site 4 tributary	<.1 (.3)	1.0	2.0 (1.0)	2	.5	2.8	11.0	10	4.3	4.7	5.0	10
Site 5 main stem	3.9 (114)	5.2	7.4 (25)	8	2.3	5.2	9.6	9	NA			

HOW LAND USE AND SOIL TYPE CAN AFFECT NITRATE CONCENTRATIONS

Land use can influence the distribution and movement of chemicals used in an area. Agricultural, industrial, commercial, and transportation sites are potential sources of a variety of chemicals. Industrial organic compounds and road salt can be deposited over relatively small areas (point sources). Fertilizers and pesticides can be applied over large areas (non-point sources) of agricultural regions, such as in the central part of Dakota County. The introduction of nitrates into surface water and ground water can come from point sources, such as feed-lot operations, or from non-point sources, such as applications of nitrate-rich fertilizer to fields.

Soil type is a major determinant of the degree to which chemicals can be leached out of the soil layer. For this study, the soil layer was defined as the topmost 60 inches of unconsolidated material. The U.S. Department of Agriculture, Soil Conservation Service (SCS) has developed a method of rating soil types according to the likelihood that agricultural chemicals will be leached out of the 60-inch soil layer (A. Geincke, SCS, St. Paul, MN, oral commun., 1990). The movement of water and chemicals at depths below 60 inches is not considered. The SCS method for determining soil-leaching potential considers the combined effects of soil permeability, land-surface slope, depth to the seasonal-high saturated zone (which may include perched water), and organic matter content of the upper soil. A highly permeable soil type with low land-surface slope, low organic-matter content, and shallow depth to the seasonal-high saturated zone would have a high potential to permit leaching of chemicals through the 60-inch soil layer. In contrast, a soil type with low permeability and high land-surface slope can permit precipitation to move as overland runoff to streams rather than to percolate through the soil layer.

RELATION OF NITRATE CONCENTRATIONS IN GROUND WATER TO LAND USE AND SOIL TYPE

Water quality is not always related to a single physical factor. Several factors often must be considered simultaneously to explain differences in water-quality data. For example, nitrate concentrations in the water from 20 domestic wells and 5 shallow wells along the Vermillion River basin (fig. 1) commonly are related to the percentage of land area in agricultural use within 0.62 mile of each well (fig. 2). High nitrate concentrations, however, are not always found in ground water from areas having high percentages of agricultural land use.

An additional factor that can affect nitrate concentrations is the soil type surrounding the well site. One broad category of soil type is soil association, which comprises several soil series. A composite leaching potential for the soil association surrounding each well was calculated based on the soil leaching potentials of the primary soil series that compose the association. Nitrate concentrations in ground

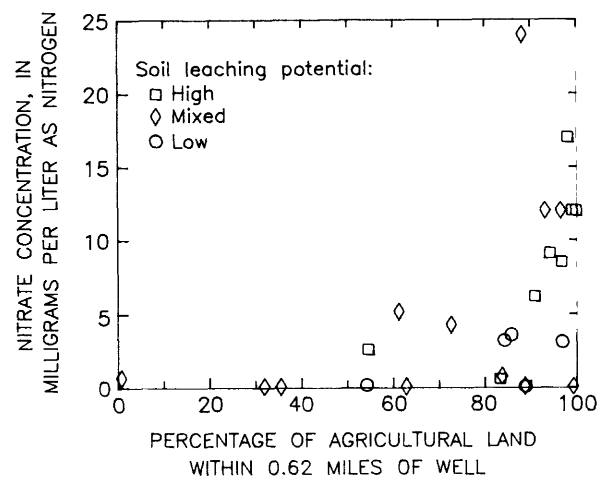

Figure 2. ***Relation of nitrate concentration in ground water to percentage of agricultural land within 0.62 miles of well for three ranges of soil-leaching potential.***

water from areas having high soil-leaching potentials were positively correlated with percentage of agricultural land use. In contrast, nitrate concentrations in ground water from areas having low soil-leaching potentials were generally small (less than 0.1 to 3.6 milligrams per liter nitrate nitrogen) regardless of percentage of agricultural land use. Some of the wells were completed in areas having a mixture of soils with high and low leaching potentials. Nitrate concentrations in ground water from areas having mixed soil-leaching potentials and high percentages of agricultural land use were variable and possibly are dependent on the local distribution of soils with high leaching potential. Water from six of the wells located in areas having high or mixed soil-leaching potentials had nitrate-nitrogen concentrations ranging from 12 to 24 milligrams per liter. These concentrations are above the 10-milligram per liter limit set as the drinking-water standard by the Minnesota Pollution Control Agency and as the maximum contaminant level by the U.S. Environmental Protection Agency in 1988.

SUMMARY AND CONCLUSIONS

Water quality can be influenced by many factors including land use, soil type, geology, and depth to water table. Water quality often can be related to the source of the water, such as surface water, shallow ground water, or deeper ground water. Near the Vermillion River in Dakota County, nitrate concentrations in both surface water and shallow ground water were similar and generally much higher than those in deeper ground water. High nitrate concentrations in wells in Dakota County generally were correlated with the percentage of surrounding agricultural land use and leaching potential of the soil association surrounding each well.

SELECTED REFERENCES

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