U.S. Department of the Interior
U.S. Geological Survey

RELATION OF LAND USE TO NITRATE IN THE SURFICIAL AQUIFER ALONG THE STRAIGHT RIVER, NORTH-CENTRAL MINNESOTA, 1992-93

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INTRODUCTION

The U.S. Geological Survey studied the relation of land use to nitrate concentrations in the surficial aquifer along the Straight River near Park Rapids in north-central Minnesota (see adjacent map) during 1992 to 1993. Concern about health hazards to humans and livestock from use of ground water contaminated by nitrate prompted the study.

Data collected for this study included: (1) water levels from 38 monitoring wells; (2) nitrate-nitrogen concentrations in ground-water samples from 34 monitoring wells; and (3) land use determined for 2.5-acre parcels throughout the study area. Eighteen of the monitoring wells were installed as nested pairs; the other 20 wells were installed singly. The wells were screened near the water table except the deep wells of each nested pair, which were screened near the bottom of the aquifer.

BACKGROUND

Why do people need to know how much nitrate is in the ground water?

Ground water with high nitrate concentrations may be unsafe to drink. The U.S. Environmental Protection Agency has established a limit of 10 mg/L (milligrams per liter) for nitrate nitrogen in drinking water (U.S. Environmental Protection Agency, 1994). Children and infants who drink water with nitrate nitrogen in excess of this limit are at risk to develop an anemic condition commonly known as "blue baby syndrome". Ruminant livestock animals, such as cows, may be harmed by drinking water with nitrate nitrogen in excess of 100 mg/L.

What is nitrate and where does it come from?

Nitrate is an inorganic form of nitrogen typically formed at or near land surface by the following two-step biochemical process: (1) chemical breakdown of organic nitrogen to form ammonium (ammonification); (2) followed by oxidation of ammonium to form nitrate (nitrification) (see figure below). Some nitrate dissolves in water from rain, snowmelt, and irrigation at or near the land surface and moves downward with water that seeps to the water table (leaching).

Location of study area in Minnesota

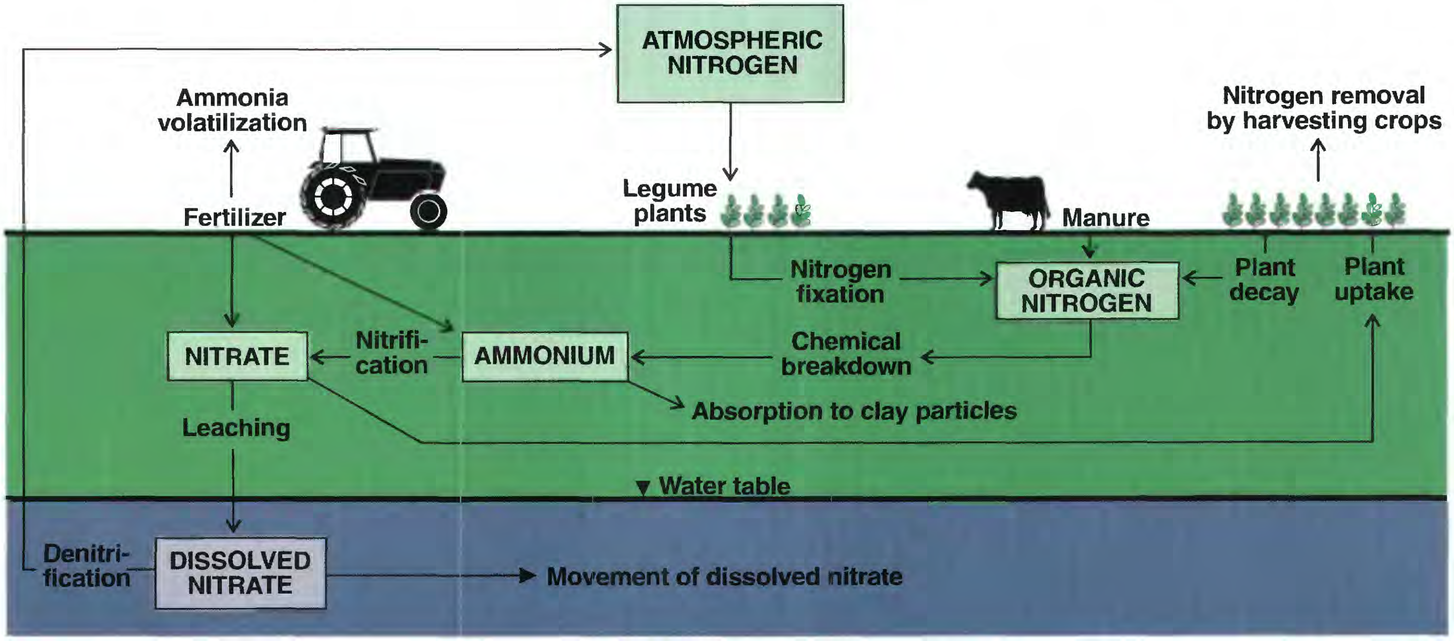
Nitrate-nitrogen concentrations less than or equal to 3 mg/L generally are considered to be natural background levels attributable to soil organic nitrogen (Anderson, 1993). Concentrations greater than 3 mg/L generally are considered to be attributable to sources such as: (1) nitrogen fertilizer (may contain nitrate, ammonium, anhydrous ammonia, or urea) applied to croplands and lawns; (2) livestock animal wastes (contains organic nitrogen and ammonium) stored in feedlots and spread onto fields; and (3) waste-water seepage (contains organic nitrogen and ammonium) released from household septic systems.

What happens to nitrate in the ground water?

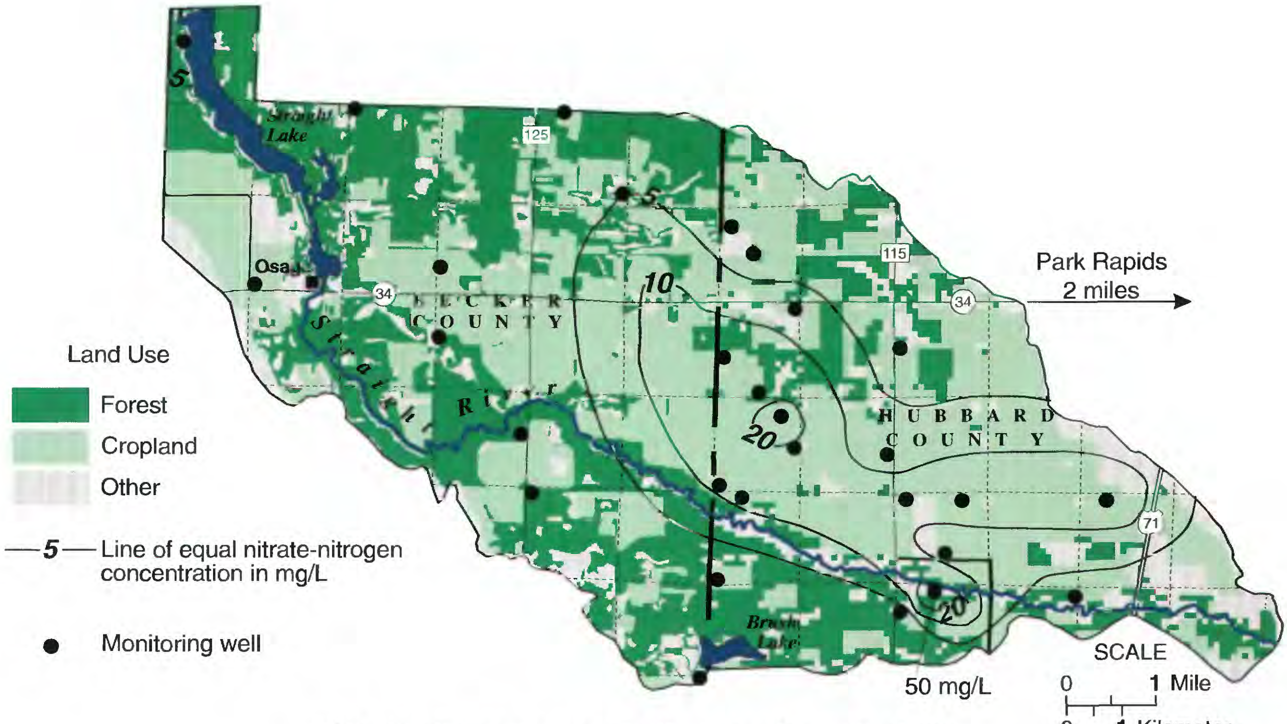
Nitrate may be biochemically removed from the ground water if the concentration of dissolved oxygen is small. Under these conditions bacteria can convert nitrate to nitrogen gas (denitrification). Nitrate in ground water can be diluted by mixing with ground water that has very little nitrate. Thus the concentration of nitrate in ground water is likely to decrease with increased distance from the nitrate sources.

Is high nitrate in ground water a widespread problem?

The number of recently documented cases of illness in humans and livestock caused by nitrate-contaminated ground water is small. However, nitrate contamination of ground water is an important environmental issue because of the potential health hazards. Evidence of nitrate contamination of ground water has been reported for many areas. A



Principal pathways of nitrogen cycle in an agricultural setting



Nitrate-nitrogen concentration near the water table in the Straight River area

recent study of near-surface aquifers in agricultural areas of the midcontinental United States found that 6 percent of nearly 600 ground-water samples collected from about 300 wells had more nitrate than the U.S. Environmental Protection Agency drinking water limit (Kolpin and others, 1994).

ENVIRONMENTAL SETTING

Cultivated croplands cover about one-half, and forests extend over slightly more than one-third, of the study area (see map above). Other land uses include livestock production, pasture, residential development, wetlands, and municipal waste-water treatment. Potatoes, corn, beans, and to a lesser extent small grains, are grown on the cultivated croplands. Typical application rates of nitrogen fertilizer (as total pounds of nitrogen per acre) on the croplands are 235 for potatoes, 140 for corn, and 110 for beans. Irrigation of the croplands has increased significantly during the past 25 years.

Aquifers in the study area consist of surficial and buried glacial outwash deposits of sand and gravel. The surficial aquifer is part of the Pineland Sands aquifer, which extends over most of the study area. This aquifer is unconfined. Low-permeability earth materials do not overlie this aquifer to retard downward movement of water from land surface into the aquifer. This aquifer is vulnerable to land-surface sources of contamination. The buried outwash aquifers are confined by overlying layers of low-permeability till and lake sediments. The vulnerability of these aquifers to land-surface sources of contamination is small. These aquifers are not mapped. Crystalline bedrock that underlies the glacial deposits is not used as a source of ground-water supply.

POTENTIAL SOURCES OF NITRATE

The areal variation of nitrate concentrations in ground water in the surficial aquifer (based on median values determined for the monitoring wells) was compared to the areal distribution of the cultivated croplands and forests (see map above). This comparison was done to evaluate these land uses as potential nitrate source areas.

The areal variation of nitrate concentrations indicated increased concentrations from areally distributed nonpoint sources. Ground water near the water table had nitrate-nitrogen concentrations that ranged from 5 to a little greater than 20 mg/L in the central and east-central parts of the study area. These areas generally were coincident with cultivated croplands. The concentrations generally were less than 5 mg/L in the western part and along the northern and southern sides of the study area. Land use in this part of the study area was mostly forest. Ground water near the water table had a locally high concentration of 50 mg/L (based on the median value determined for a single monitoring well) in the southeastern part of the study area. This area was downgradient from a feedlot and manured field. Results of this study indicate that cultivated croplands and a feedlot and manured field were linked to increased nitrate concentration.

CITED REFERENCES:

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Kolpin, D.W., Burkhart, M.R., and Thurman, E.M., 1994, Herbicides and nitrate in near-surface aquifers in the midcontinental United States, 1991: U.S. Geological Survey Water-Supply Paper 2413, 34 p.

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SUGGESTIONS FOR ADDITIONAL READING:

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