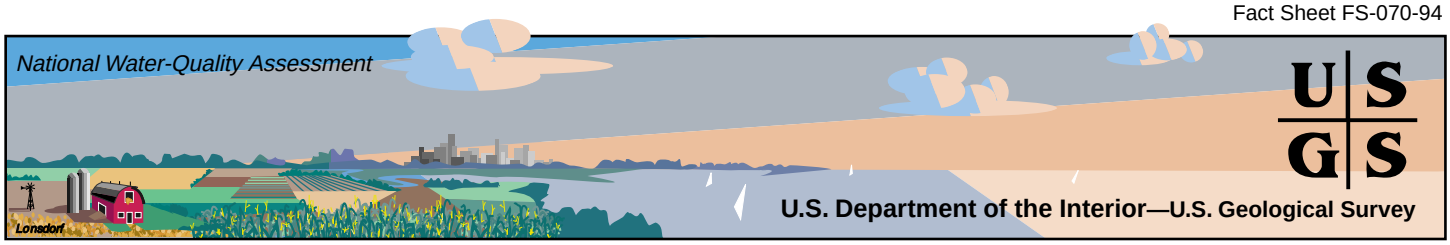
Fact Sheet FS-070-94



Nitrate in Ground Water in the Western Lake Michigan Drainage Basin, Wisconsin and Michigan

by David A. Saad

INTRODUCTION

In 1991, the U.S. Geological Survey began the nationwide implementation of the National Water-Quality Assessment (NAWQA) Program. The long-term goals of the NAWQA Program are to describe the status and trends in the quality of a large, representative part of the Nation's surface- and ground-water resources and to provide a sound, scientific understanding of the primary natural and human factors that affect the quality of these resources. The program (as currently planned) consists of 60 study-unit investigations that include parts of most major river basins and aquifer systems in the country. The Western Lake Michigan Drainage Basin encompasses a 20,000-square-mile area in eastern Wisconsin and the Upper Peninsula of Michigan that drains to Lake Michigan and Green Bay (fig. 1).

An important component of the NAWQA Program is the retrospective analysis of available water-quality data. This fact sheet is derived from a detailed analysis of available nutrients and suspended sediment data and describes the distribution of dissolved nitrite plus nitrate as nitrogen (N) concentrations, which is one of the most common and widespread nutrient analyses of ground-water samples collected in the study area. Throughout the study area, nitrite concentrations in ground water generally are negligible, therefore, concentrations of nitrite plus nitrate as N are referred to hereafter as "nitrate-N" concentrations. Concentrations are described for the study area as a whole and in relation to three interrelated factors that affect nitrate concentration in ground water-land use, well depth, and texture of surficial deposits.

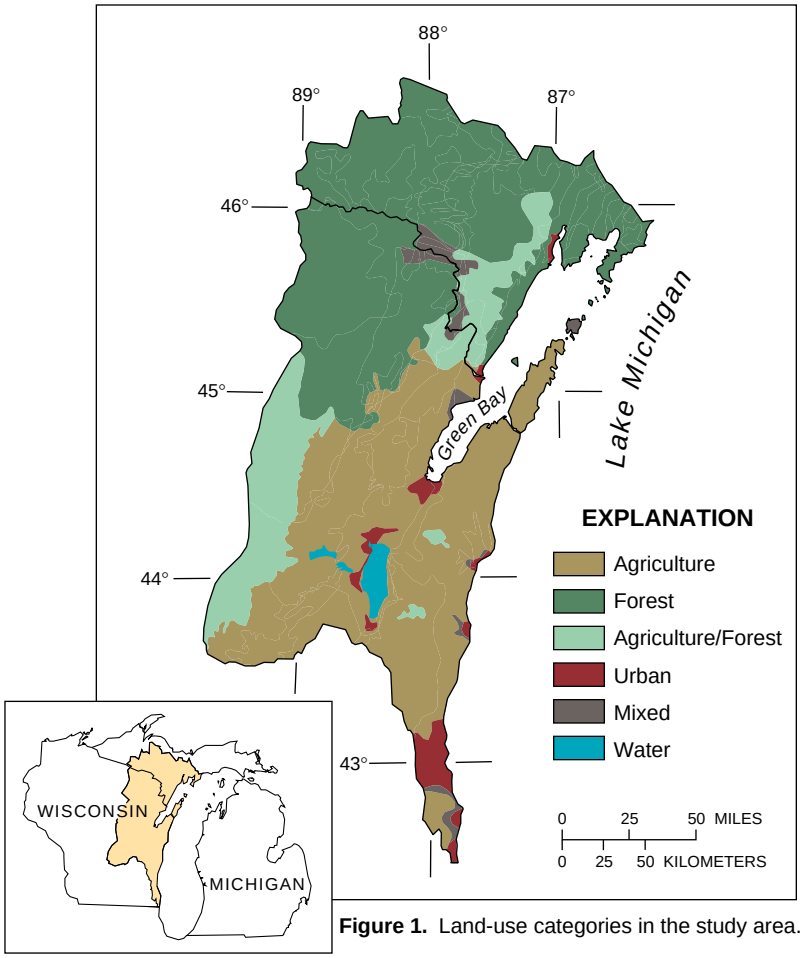


Figure 1. Land-use categories in the study area.

NITRATE IN GROUND WATER

In the study area the median concentration of dissolved nitrate-N in ground water was 0.40 milligram per liter (mg/L). Water from about 10 percent (81 of 789) of the wells sampled had concentrations that were higher than the U.S. Environmental Protection Agency's maximum contaminant level (MCL) of 10 mg/L. High concentrations of nitrate in water can be harmful if consumed by warmblooded animals. After nitrate is converted to nitrite within the gastrointestinal tract, nitrite reacts with hemoglobin in the blood and impairs oxygen transport to tissues. Nitrate is introduced into ground water naturally from decomposing organic matter and from soils and rocks. Other potential sources of nitrate include septic systems, sewage effluent, industrial discharges, and atmospheric deposition; however, the largest areas that have nitrate-N concentrations in ground water that approach the MCL generally result from application of nitrogen-rich fertilizer and manure to the land surface. One of the greatest water-quality concerns in the study area is the effects of land use on nitrate concentrations in ground water.

Relation to Land Use

The effects of land use on nitrate concentrations in ground water were examined by dividing the study area into five subareas on the basis of percentage of land use-agriculture/forest [approximately (~) 50 percent agriculture and ~40 percent forest, hereafter referred to as "ag/forest"], agriculture [greater than (>) 75 percent of total land use], forest (>75 percent of total land use), urban (>65 percent of total land use), and mixed (fig. 1). Mixed areas were defined as small isolated areas with two or more land uses and were not included in analyses. Nitrogen inputs, which were calculated from fertilizer and manure applications, nitrogen fixation, and atmospheric deposition, were highest in the agriculture areas followed by ag/forest, urban, and forest areas. If all other factors remained the same, then nitrate concentrations in ground water should correspond to rates of input. However, the highest median concentration of nitrate-N (5.45 mg/L), was found in the ag/forest areas. This is an order of magnitude higher than the median concentrations in agriculture and forest areas (0.32 and 0.23 mg/L, respectively) and two orders of magnitude higher than that in

urban areas (0.05 mg/L). These results show that the areas with the largest nitrogen inputs do not necessarily correspond to the areas with the highest nitrate concentrations in ground water. Other factors that affect the concentration of nitrate in ground water, such as well depth and texture of surficial deposits, need to be examined.

Relation to Well Depth

Concentrations of nitrate-N in ground water generally decreased with well depth in the study area. To illustrate this trend, sampled wells were divided into five well depth categories-0 to 50, 51 to 100, 101 to 150, 151 to 200, and >200 feet (ft) below land surface. The highest median concentration (3.10 mg/L) was found in the shallowest wells (0-50 ft). This is an order of magnitude higher than median concentrations in the 51-100, 101-150, and 151-200 ft categories (0.60, 0.46, and 0.15 mg/L, respectively) and nearly two orders of magnitude higher than median concentrations in wells >200 ft deep (0.07 mg/L).

The observed concentrations of nitrate in ground water, by land-use category, are related to well depth, also by land-use category. The ag/forest area had the shallowest wells (based on median well depth) followed by agriculture and forest areas; and the highest median nitrate-N concentration again followed by agriculture and forest. The deepest wells and lowest nitrate-N concentrations were in urban areas. This pattern indicates that nitrate-N concentrations may depend on well depth alone. To test this supposition, nitrate-N concentrations, by land-use category, were compared in water from shallow wells (less than 100 feet deep). If well depth was the primary factor in determining nitrate-N concentrations in ground water, then each land-use category would be expected to have similar nitrate-N concentrations in water from shallow wells. This was not the case though. The highest median concentration was still found in the ag/forest area (6.00 mg/L) followed by agriculture, forest, and urban (1.30, 0.21, and 0.05 mg/L, respectively). Even though well depth is strongly correlated with nitrate-N concentration in ground water, the correlation itself does not explain the mechanisms behind subsurface nitrate transport; the correlation explains only that nitrate is attenuated, diluted, or denitrified with depth below land surface. Other factors, such as texture of surficial deposits, need to be examined to help explain nitrate-N concentrations in ground water.

Relation to Texture of Surficial Deposits

Nitrate enters the ground-water system by moving with recharge at the land surface (from precipitation or irrigation) through surficial deposits to the water table. Water (and contained nitrates) moves from the land surface to the water table at different rates depending on the texture of surficial deposits. Generally, water moves slowest through clay and fastest through sand and gravel. The effects of texture of surficial deposits on concentrations of nitrate-N in ground water were evaluated by dividing the study area into five subareas on the basis of texture of surficial deposits-clay, clay/sand, loam, loam/sand and gravel, and sand/sand and gravel (fig. 2). Subareas identified as clay/sand, loam/sand and gravel, and sand/sand and gravel represent areas with both texture types that have been lumped together. Most of the wells in the study area were completed in areas underlain by either clay or sand/sand and gravel. Nitrate-N concentrations in areas underlain by clay were much lower than those in areas underlain by more permeable sand/sand and gravel (medians are 0.20 and 1.60 mg/L, respectively).

Examination of the relation between texture of surficial deposits and land use clarifies the observed pattern of nitrate-N concentrations by land-use category. The area categorized as urban is almost completely underlain by clay, a fact that helps to explain why ground water in this area had the lowest concentrations of nitrate-N. In contrast, the ag/forest areas are completely underlain by sand/sand and gravel deposits and had the highest nitrate-N concentrations. Most of the agriculture land-use area is underlain by clay. Even though this area had the highest nitrogen inputs, the underlying clay probably limited the recharge of water that contained high concentrations of nitrate-N.

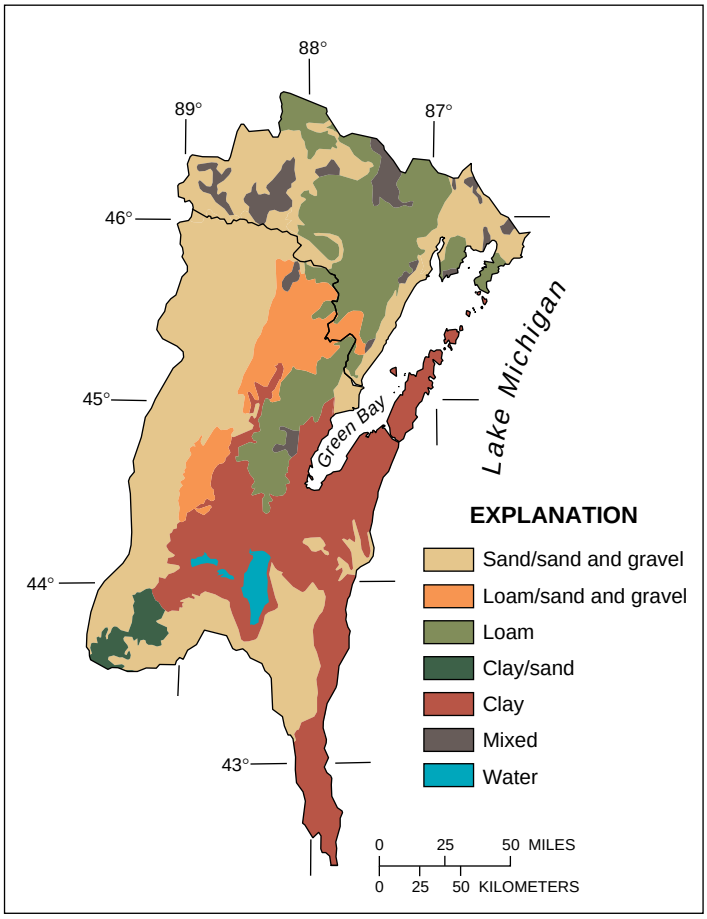


Figure 2. Texture of surficial deposit categories in the study area.

SUMMARY

Nitrate-N concentrations in ground water in the Western Lake Michigan Drainage Basin were directly related to the land use near a well, the depth of the well, and the texture of surficial deposits that underlie the area around the well. In general, ground water in areas with agriculture or ag/forest land use had higher concentrations of nitrate-N than that in urban and forest areas, water from shallow wells generally had higher concentrations of nitrate-N than that from deep wells, and ground water in areas underlain by sand and gravel generally had higher concentrations than that in areas underlain by clay.

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