# Nitrate in Kansas Groundwater

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## Introduction

Groundwater is the major source of drinking water for 70% of Kansas residents. In rural areas, 85% of the population relies on groundwater. Therefore, contaminants that may cause health problems, such as nitrate, are of significant concern. For owners of private wells, the issue of groundwater contamination is particularly serious. Most private domestic supplies are neither tested nor treated on a routine basis.

Nitrate is the most common inorganic contaminant in Kansas groundwater. Previous studies have found that about 30% of domestic wells in Kansas have nitrate levels greater than the Maximum Contaminant Level (MCL) for public drinking water (Steichen et al., 1988; Spalding and Exner, 1993; Townsend and Young, 1995; Townsend, 1996). Concentrations seem to be increasing in many areas of the state (Townsend et al., 1996; Townsend et al., 1997). The purpose of this circular is to describe nitrate, its sources, the extent of the nitrate problem in Kansas, and how groundwater can be protected from nitrate contamination.

## Background

Nitrogen (N) is an important plant nutrient, absorbed primarily in the form of nitrate ($NO_3^-$). The other prominent forms of nitrogen are atmospheric nitrogen gas ($N_2$), organic nitrogen, and ammonium ($NH_4^+$), the latter two of which can attach to soil particles. In the soil zone, most forms of nitrogen will be converted to nitrate by bacterial processes; this conversion is termed nitrification (fig. 1).

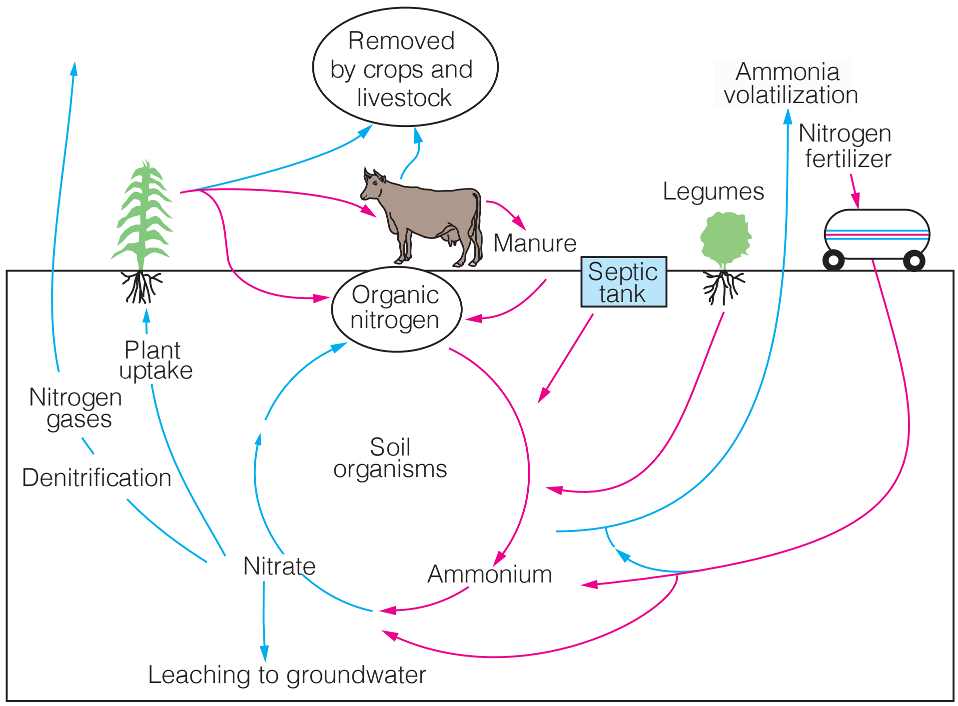


*Figure 1. Simplified illustration of the nitrogen cycle.*

Nitrate readily dissolves in water and, once there, is hard to remove. Nitrate concentration in groundwater is commonly reported as "nitrate as nitrogen" (nitrate-N) — that is, only the nitrogen in the nitrate molecule ($NO_3^-$) is counted. The U.S. Environmental Protection Agency (EPA) and the Kansas Department of Health and Environment (KDHE) set the MCL for drinking water at 10 milligrams/liter (mg/L) nitrate-N. Nitrate consumption can pose health risks. One of these, methemoglobinemia (or blue baby disease), is caused by bacterial conversion of nitrate to nitrite ($NO_2^-$) in the intestinal tract. Nitrite interferes with the oxygen-carrying capability of the blood and the victim appears "blue." This condition can be fatal both to human infants and to some young animals.

Background levels for natural nitrate-N in groundwater are nearly always less than 3 mg/L (Madison and Brunett, 1984). Concentrations above 3 mg/L indicate that nitrate from non-natural sources such as human or animal waste or fertilizers has entered the groundwater.

## Sources of Nitrate

As fig. 1 illustrates, sources of nitrogen to the soil or land surface include fertilizer, legumes that fix nitrogen in the soil, and animal wastes. Losses include crop uptake and removal, conversion of nitrate to nitrogen gases (denitrification), ammonia volatilization, and leaching of nitrate from the soil zone to groundwater. Nitrogen at or near the land surface may move downward toward the water table by leaching with water (precipitation or irrigation water, for example).

It is useful to divide the sources of nitrogen contamination into nonpoint and point sources. Nonpoint sources are diffuse, as opposed to point sources, which are single, identifiable sources of contamination. Nonpoint sources of nitrate include long-term, widespread overuse of chemical or manure fertilizers (on cropland, lawns, or golf courses) and long-term leaks in sewer lines. Point sources include areas of concentrated livestock confinement, leaky septic or sewer systems, and areas of chemical or manure storage or spills. Unplugged abandoned wells and boreholes, improperly constructed wells, and sinkholes are avenues that can allow rapid contamination of groundwater from point sources at the surface. Point sources may result in extremely high nitrate concentrations in localized areas.

Nitrate in groundwater is frequently associated with agriculture, the largest industry in Kansas. Plants have basic needs: water, nitrogen, and other nutrients. Statistics from the Kansas Department of Agriculture (KDA) show that sales of nitrogen fertilizers increased dramatically from the mid-1940s to the present (fig. 2). In 1997, more than 700,000 tons were sold, which gives an approximate idea of the amount actually used. As fig. 2 shows, during the same period, the number of water rights issued also increased (Will Gilliland, KDA, Division of Water Resources, 1998, personal communication). Because more fertilizer is generally applied to irrigated than non-irrigated cropland and because irrigation increases the amount of water available for leaching, the potential for nitrate leaching into groundwater from unused fertilizer increases.

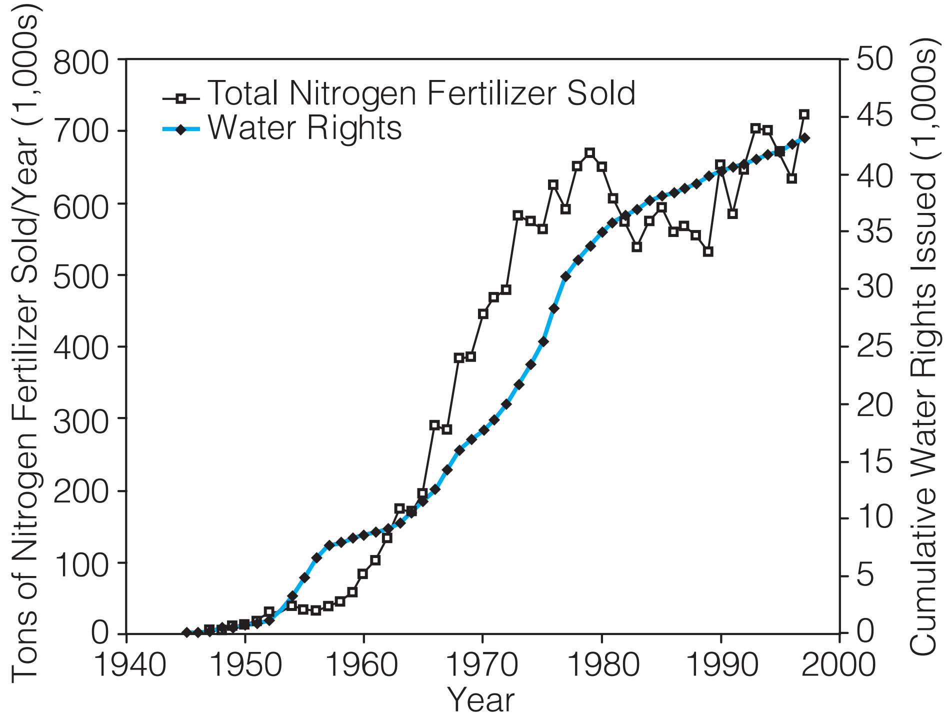


*Figure 2. Total nitrogen fertilizer sold in Kansas from 1945 to 1997 (Kansas Department of Agriculture, 1998) and the cumulative water rights issued from 1945 to 1997 (Will Gilliland, KDA, Division of Water Resources, 1998, personal communication).*

*Table 1. Nitrogen from animal wastes in Kansas. Population statistics from 1990 U.S. census as reported by the Environmental Working Group, 1998; Animal statistics from Kansas Department of Agriculture, 1997.*

| Source of Nitrogen | Amount of Nitrogen | Approx. Number of Animals/Humans | Tons of Potential Available Nitrogen Per Year |
|---|---|---|---|
| **Dairy Cattle** | 10 lb/ton manure | 79,000 | 4,680 |
| **Beef Cattle** | 14 lb/ton manure | 2.35 million | 180,000 |
| **Swine** | 10 lb/ton manure | 1.305 million | 9,530 |
| **Humans Using Septic Systems** | 14.5 lb/person/year | 765,000 | 5,550 |

Animal-waste sources of nitrogen include feedlots, manure applied as fertilizer, and septic systems. Of these, the biggest source of nitrogen is the waste from beef cattle (table 1). Because of the potential volume of nitrogen available from both fertilizer and animal sources, proper management for control of all sources of nitrogen is vital in protecting the state's groundwater.

## Occurrence of Nitrate in Kansas Groundwater

Studies in Kansas show that many factors affect nitrate concentration in groundwater. These include soil characteristics, land-use practices, depth to the water table, depth of the well, age and construction of the well, and the amount of irrigation. Generally, areas such as south-central Kansas, which have relatively permeable (sandy) soils, a shallow water table, shallow wells, and irrigated farming, are most susceptible to nitrate contamination.

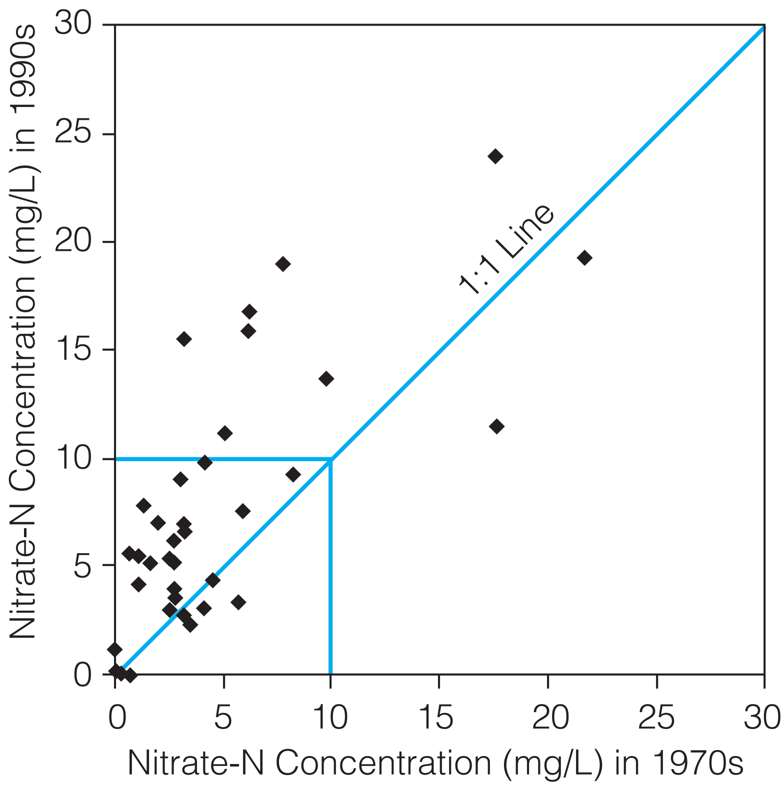


*Figure 3. Comparison of nitrate-N concentrations in 36 irrigation wells sampled in the 1970s and in the 1990s. The 1:1 line shows where the values would plot if there were no change from the 1970s to the 1990s. Points above the line indicate an increase in nitrate-N concentrations; those below indicate a decrease. Box at 10 mg/L indicates U.S. EPA drinking-water limit.*

Recent data compiled by the Kansas Geological Survey suggest that water in older (pre-1975) wells has higher concentrations of nitrate-N than newer wells. In 1975, regulations were adopted concerning water-well construction and abandonment by KDHE.

During the 1990s, Survey staff performed nitrate-N analyses on 36 irrigation wells that had been sampled in the 1970s. All wells are located in western or south-central Kansas. In the majority of the samples, nitrate-N concentrations increased from the 1970s to the 1990s, indicating that nitrate is moving from the surface to groundwater (fig. 3). This may be a function both of long-term irrigated farming in the area and the age of the wells. (Wells built before 1975 generally have the annular space filled with gravel pack to near land surface, potentially allowing for near-surface water flow down the wellbore to groundwater).

## Protecting Groundwater from Nitrate Contamination

In general, the means to protect groundwater from surface contamination include proper well construction with at least 20 feet of grout to prevent surface and near-surface flow of water to groundwater; wellhead-protection programs around public and domestic water supplies; maintenance and correct closure of septic systems; proper plugging of abandoned wells; mixing chemicals away from wells, streams, and ponds; and correct disposal of excess fertilizer and other chemicals. Most of these measures are aimed at preventing contaminants at the surface from entering groundwater directly via wells and boreholes. The importance of proper well construction and proper plugging of abandoned wells cannot be overstressed. All the Groundwater Management Districts, as well as the State Conservation Commission and the Kansas Farm Bureau, have programs to assist with well plugging.

Agricultural-management practices that may reduce the potential for nitrate contamination of groundwater include: (1) soil testing to determine the volume of nitrogen available; (2) determination of yearly fertilizer-application rate by use of a nitrogen-budget calculation that gives credits for existing sources of nitrogen, including manure fertilizer, nitrogen fertilizer, legumes, stored soil nitrogen, and nitrate in irrigation water; (3) timing of fertilizer (and water) application to the needs of the plants, including split applications; (4) use of nitrification inhibitors such as N-Serve® when applying fertilizer to delay the formation of nitrate; (5) utilization of crop-rotation practices instead of continuous cropping; (6) use of cover crops to minimize over-winter nitrogen losses; and (7) integration of livestock and crop production (including crop rotation) to recycle nutrients and use nitrogen efficiently. More information on most of these practices is available from the Kansas State University Cooperative Extension Service (address listed at end of report).

A simple equation for calculating the amount of nitrogen in irrigation water can determine the nitrogen credit as described in (2) above:

**Depth of water applied (inches) x nitrate-N concentration of water applied (mg/L) x 0.227 = lb nitrogen/acre**

For example, applying 18 inches of irrigation water with a nitrate-N concentration of 5 mg/L represents:

**18 (inches of water) x 5 (mg/L) x 0.227 = 20 lbs nitrogen/acre**

That 20 lbs nitrogen/acre applied in the irrigation water represents 20 lb/acre of fertilizer nitrogen that do not have to be applied. Using such a nitrogen credit and applying less fertilizer saves money while helping to protect groundwater.

Efforts to control feedlot waste include (1) riparian-zone control to prevent surface runoff of waste to streams and ponds, (2) correctly built storage lagoons for liquid waste, and (3) rehabilitation of abandoned and intermittently used feedlots by growing plants to utilize excess nitrogen in soil.

### Summary

Nitrate contamination of groundwater is occurring in Kansas, and nitrate concentrations are increasing in many areas of the state. Nitrate contamination may occur in both rural and urban settings but is often related to agricultural practices. Certain management practices can reduce the risk of nitrate entering groundwater.

By the time contamination is detected, the overlying unsaturated zone may be enriched with the contaminant. Remedial action may take decades to improve water quality, and expensive treatment or alternative sources may be required to provide high-quality water. It is important to prevent nitrate contamination of groundwater, rather than to wait for contamination to occur and attempt to rectify it. Prevention measures focus on avoiding direct contamination of groundwater from the surface through wells and boreholes and controlling the sources of nitrate contamination.

## Additional Sources of Information

More information about nitrate contamination in Kansas groundwater can be obtained by contacting the Cooperative Extension Service at Kansas State University (Extension Agronomy, 2004 Throckmorton PSC, 1712 Claflin Road, Manhattan, KS 66506-0110, 785-532-6101, https://www.agronomy.k-state.edu/extension/) and the U.S. Geological Survey's Kansas Water Science Center (https://www.usgs.gov/centers/kansas-water-science-center).

Other sources of information include county health departments, local Farm Bureau offices, and local Natural Resource Conservation Service District Offices.

### References


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KANSAS GEOLOGICAL SURVEY
The University of Kansas

The Kansas Geological Survey (KGS) is a research and service division of the University of Kansas that investigates and provides information about the state's natural resources. KGS scientists pursue research related to surface and subsurface geology, energy resources, groundwater, and environmental hazards. They develop innovative tools and techniques, monitor earthquakes and groundwater levels, investigate water-quality concerns, and map the state's surface geology.

The KGS has no regulatory authority and does not take positions on natural resource issues. The main headquarters of the KGS is in Lawrence in the West District of the University of Kansas, and the Kansas Geologic Sample Repository of the KGS is in Wichita.


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