NITRATES AND GROUNDWATER

Water Quality IV-b

Groundwater supplies about 50% of the drinking water in the United States. In rural areas, as much as 85% of the drinking water is from groundwater. Nearly 70% of Kansans rely on groundwater as their source of drinking water. Consequently, protection of groundwater from contamination by any substance that might cause health problems is a serious concern.

One potential contaminant of groundwater is nitrate (NO_3). A recent survey of rural water wells in Kansas found 28% of the wells with nitrate levels higher than the National Public Health Service drinking water standard.

This fact sheet addresses nitrates and their effect on groundwater including: human and livestock health concerns, extent of nitrates in groundwater, sources of nitrates in groundwater, and ways to minimize the risk of nitrate contamination of groundwater.

Health Concerns

Human: Humans ingest nitrates in food and water, and nitrates are absorbed readily from the digestive tract. In older children and adults, nitrates are ingested, absorbed, and excreted promptly in the urine. Healthy human adults can consume fairly large amounts of nitrate with little known effect.

Infants under 3 to 6 months old, however, are susceptible to nitrate poisoning because of bacteria present in their digestive systems at birth. Because newborn infants have little acid in the digestive tract they depend on these bacteria to help digest food. Generally, by the age of 3 to 6 months, hydrochloric acid levels in the baby's stomach increase and kill most of the bacteria that convert nitrate to nitrite.

The primary health concern of nitrates is due to the reduced form of nitrate called "nitrite." The bacteria in the digestive tract of young infants can change nitrate into nitrite, which is toxic. The nitrite is absorbed and enters the bloodstream where it reacts with the oxygen carrying hemoglobin, forming a compound called "methemoglobin." High levels of methemoglobin interfere with the blood's ability to carry oxygen. As oxygen levels decrease, subjects may show signs of suffocation. This condition is called "methemoglobinemia."

The major symptom of methemoglobinemia is bluish skin color, most noticeably around the eyes and mouth. Death can occur when 70% of the hemoglobin has been converted to methemoglobin. Methemoglobinemia can be treated successfully with an injection of methylene blue, which changes methemoglobin back to hemoglobin. Treatment must occur quickly, however.

Infant deaths from methemoglobinemia, sometimes called "baby blue", are rare but have been documented: some have been linked to high levels of nitrate in well water. Doctors now recommend using bottled water to make formula when nitrate levels exceed the U.S. Public Health Service drinking water standard of 44 parts per million(ppm). With one possible exception, no breast-fed infants have developed methemoglobinemia - an observation attributed to rapid nitrate excretion by the mothers.

Livestock: Nitrate poisoning is most likely in ruminant animals such as cattle and sheep. Bacteria present in the rumen convert nitrate to toxic nitrite. Monogastric animals such as swine and chickens have no rumen and most of the nitrate is rapidly eliminated in the urine. Young monogastric animals, like human infants, have a high degree of susceptibility until their digestive systems develop. Horses are monogastric, but their large cecum acts much like a rumen in that bacteria present are capable of converting nitrate to nitrite. Because of this, horses are more susceptible to nitrite poisoning than other monogastric animals.

While some plants naturally contain potentially harmful levels of nitrate, water rarely does. High nitrate water is generally a health hazard to animals only when it adds to high nitrate concentrations already present in some feeds.

Symptoms of methemoglobinemia in animals include: lack of coordination, labored breathing, blue coloring of mucous membranes, vomiting, and abortions. Dairy cows, however, can have reduced milk production without showing any symptoms. If animals show signs of nitrate poisoning or a problem is suspected, a veterinarian should be consulted to determine if nitrate is the problem and, if necessary, administer the antidote-an injection of methylene blue.

Water Testing: If nitrates in drinking water are suspected for humans or livestock, a routine water sampling and testing program should be initiated so nitrate levels in the water can be monitored. Nitrates are undetectable in water or feeds without testing as they are colorless, odorless, and tasteless. In Kansas, the Department of Health and Environment or several private testing laboratories can perform this service.

Most laboratories report the nitrate content as parts per million (ppm) of either nitrate (NO_3) or nitrate-nitrogen (NO_3-N). To interpret the results, it is critical to know if results are reported as NO_3 or NO_3-N. To convert NO_3-N to NO_3, multiply by 4.4. For example, 10 ppm NO_3-N is equivalent to 44 ppm NO_3. The following table gives some general guidelines for water use.

Guidelines for Use of Water with Known Nitrate Content

Nitrate (NO_3) level(ppm)	Nitrate-Nitrogen (NO_3-N) level (ppm)	Interpretation
0-44	0-10	U.S. Public Health Service standard is 44 ppm NO_3 or 10 ppm NO_3-N. Safe for humans and livestock
45-88	11-20	Generally safe for human adults and livestock. Do not use for human infants.
89-176	21-40	Generally acceptable for human adults and all livestock unless food or feed sources are very high in nitrates.
177-440	41-100	Risky for human adults and young livestock. Probably acceptable for mature livestock if feed is low in nitrates.
Over 440	over 100	Should not be used.

Extent of Nitrates in Groundwater

Even though nitrates, both naturally occurring and from other sources, are a common ground water contaminant in the United States, the severity of nitrate contamination is hard to assess Researchers agree that nitrate concentrations in unpolluted groundwater seldom exceed the 44 ppm standard. Recent United States Geological Survey (USGS) data show that almost every state has areas where nitrate levels exceed the standard. About 6 percent of the total wells sampled in this survey had nitrate concentrations exceeding 44 ppm

The USGS study, while documenting that nitrates are commonly found in groundwater, was not a statistically valid sample of groundwater conditions. Some of the wells were sampled because of suspected contamination, and there was poor sampling consistency.

A recent Environmental Protection Agency (EPA) study of rural water supplies may provide more valid data. Nationwide, this survey found only 2.7% of rural wells exceeding the 44 ppm standard.

Several recent studies, however, reveal trends that are a concern. Work in Nebraska, Iowa, and Kansas has shown localized areas where nitrates have been increasing. For example, surveys conducted along the upper Des Moines River Basin in Iowa found 20-30% of the wells exceed the 44 ppm drinking water standard for nitrates.

In Kansas, a random survey of 104 farmstead wells conducted from December 1985 through February 1986 showed 28% of the wells had nitrate levels of 44 ppm or higher. Of the wells with nitrate levels exceeding 44 ppm, about half exceeded 88 ppm.

While the data in general indicates that nitrate contamination of groundwater has not been a widespread problem, it is a concern in some areas of the Midwest, including Kansas and adjacent states.

Sources of Nitrates in Groundwater

Understanding where nitrates come from and how they reach groundwater requires a knowledge of two aspects of our natural world:the nitrogen cycle and groundwater recharge.

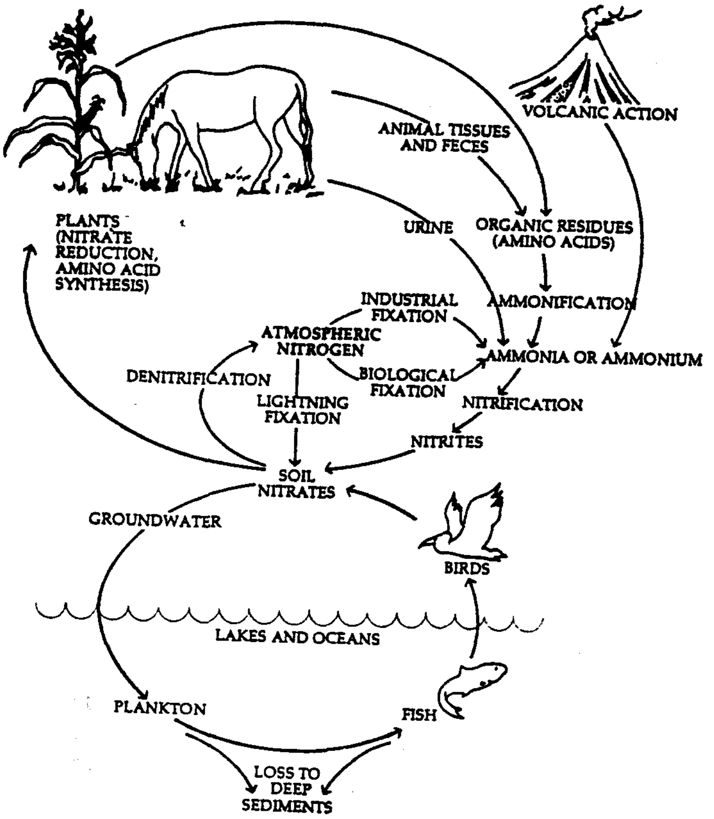
The nitrogen cycle: Worldwide, nitrogen is the plant nutrient most limiting for food production. Since early times, people have sought to add nitrogen to crops by using animal wastes, human wastes, legumes, or fertilizers.

Nitrogen is an important part of the environment. The air we breathe is 78% nitrogen gas (N_2). Nitrogen accumulates in soils during the process of soil formation. Virgin prairie soils contain as much as 6,000-10,000 pounds per acre of organically bound nitrogen. Once soil is tilled and crops are grown, organic matter content tends to decrease. As organic matter is oxidized, inorganic nitrogen is released which is available primarily as nitrate (NO_3) to the growing crops. This is shown in the illustration of the nitrogen cycle. Nitrogen can enter this cycle at several points and from several sources. This cycle operates in a native ecosystem (forest or grassland) as well as a farming ecosystem.

In some natural ecosystems, nitrogen is almost always in short supply; nitrogen cycling is very efficient, with low losses. In other natural ecosystems, however, nitrogen is abundant and loss potential is high. This explains why ground water under natural ecosystems can be high in nitrates. In today's agriculture, with greater nitrogen inputs for higher crop yields, efficiencies of nitrogen use may be lower and the potential for losses may increase. Nitrogen not taken up by the crop can reach groundwater as nitrate.

Animal manures, human wastes, composts, sewage sludge, legume crops, and green manure crops are organic sources of nitrogen. Before this nitrogen can be used by plants it must be converted to ammonium (NH_4) or nitrate (NO_3). Some nitrogen fertilizers contain nitrogen already in the nitrate form. In other fertilizers, nitrogen is in the ammonium form, which is rapidly converted to nitrate by the soil bacteria at soil temperatures above 50° F. When any nitrogen is added to the soil, either from organic or inorganic sources, it becomes a part of the soil nitrogen cycle. The total amount of nitrogen generated through the processes of the nitrogen cycle is not necessarily used by plants. When nitrogen supply is greater than the amount used by plants, potential for accumulation of nitrates in the soil and loss from the system exists, regardless of the original source of the nitrates.

The nitrogen cycle.



Nitrates can be lost from the system by leaching, denitrification, volatilization, and immobilization. From the standpoint of groundwater quality, leaching of nitrates is the only concern. The other loss mechanisms can be important in low nitrogen efficiencies, but do not contribute directly to groundwater contamination. Leaching is the downward movement of water and nitrates through the soil. The potential for nitrate leaching varies with soil type and rainfall or irrigation. Sandy soils under high rainfall or irrigation have high leaching potential.

Nitrates, moved downward by leaching, can come from many sources, not necessarily just from fertilizers, Since the downward movement of nitrate through soils was taking place before the presence of humans it's unrealistic to expect to stop or eliminate this movement. Careless use of fertilizer, or improper management of the other nitrogen sources, however, can increase the rate of movement, and magnitude of loss and must be avoided.

Groundwater recharge: Groundwater is water below the land surface that totally fills or saturates a water bearing formation. The top of this saturated zone is called the water table. Although groundwater seems to be trapped in the soil or in geologic formations, there is some movement. A water-bearing saturated zone that holds sufficient water and allows enough movement of the water to supply wells is called an aquifer.

The processes of groundwater recharge are complex. The amount of water that enters the soil and eventually recharges the groundwater varies seasonally and from area to area. During wet seasons, recharge may occur and result in shallow water tables. During dry seasons, particularly with active plant growth, water tables can be lowered. The amount of recharge and depths to the water table vary with climate, soil type, soil depth, soil permeability, topography, and geologic formations. In humid areas, considerable recharge may occur every year. In more arid regions, there may be years where no recharge occurs and water tables may be 50 to 150 or more feet deep.

In addition, different types and configurations of aquifers may affect groundwater flow. Thus, there is a chance that improvements or degradation of groundwater quality may occur over time.

As can be seen from this brief discussion of the nitrogen cycle and groundwater recharge, nitrate contamination of groundwater is a complex problem. It's clear that both nature and people can be responsible for nitrates found in groundwater. Of the human activities that contribute,nitrates, agriculture and disposal of society's wastes are by far the largest share. Society's alteration of the environment to produce food and to dispose of wastes has likely resulted in increased rates of nitrate movement and increased the magnitude of nitrate losses to groundwater.

There are, however, management practices that farmers and others can use to minimize leaching of nitrates from soils.

Reducing Nitrate Risks

The use of nitrogen fertilizers, animal and human wastes, and legume crops will continue to supply the nitrogen necessary for crop growth. However, there is no question that improved nitrogen management can reduce the potential for groundwater contamination. Several practices are important to this goal.

First, growers need to have realistic yield goals. This may be the most effective means of decreasing nitrogen losses and reducing potential groundwater pollution. Yield goals are the heart of fertilizer rate recommendations, especially for nitrogen. Setting yield goals unrealistically high results in over-fertilization and a greater potential for nitrate carryover, and potential contamination of groundwater. To arrive at an optimum nitrogen fertilizer rate, growers must consider the crop being grown, the productive capacity of the soil, and moisture availability to set a realistic yield.

A second important point is to consider all potential nitrogen sources for a crop. These include: a previous legume crop, manure, and residual nitrate already in the soil. These sources can all contribute nitrogen and may meet the total nitrogen needs of that crop. Nitrogen soil tests are recommended to determine the amount of nitrate in the soil. Research data show clearly that over-fertilization with nitrogen can increase the risk for carry-over nitrates that may eventually reach groundwater.

A third management practice is timing of nitrogen fertilizer application. On coarse textured, highly permeable soils, split or side dress applications of nitrogen generally result in increased nitrogen efficiency and decreased potential for nitrogen loss because of the shorter time between fertilizer application and crop uptake. On medium- and fine-textured soils, time of application is not critical.

Additionally, nitrification inhibitors can be used to improve nitrogen fertilizer efficiency on coarse-textured, sandy soils. These inhibitors inactivate the soil bacteria that mediate conversion of ammonium to nitrate. As long as nitrogen is in the ammonium form, it will not leach.

A final point to consider is placement of fertilizers, sludges, or manures. Much of the recent research indicates greater nitrogen efficiency in terms of crop uptake with injection or deep incorporation of nitrogen fertilizers and manure or sewage sludge. Any management practice that results in more of the applied nitrogen being taken up by the crop lessens the potential for nitrate contamination of groundwater.

Nitrogen management practices can exert a strong influence on groundwater quality. Use of the proper rate of nitrogen is probably the most important factor, but the other management practices also can be important.

Is it possible to correct a groundwater nitrate problem once it exists? It can be done, but the necessary procedures are costly and not totally effective. The best option so far, is to keep excess nitrates from entering the groundwater.

This fact points out the importance of careful selection of well sites. Wells should not be located close to septic system lateral fields, livestock confinement sites, sludge pits, lagoons, or other sites where high soil nitrogen levels would be expected.

Summary

The purpose of this fact sheet has been to provide some insight into nitrates and groundwater. High nitrate levels in water are a health concern. Nitrates can reach groundwater from many sources and certainly not all are of agricultural origin. Whatever the source, we need to be concerned about minimizing nitrate movement into our groundwater.

In short, we do not have a complete picture of groundwater contamination by nitrates. We do, however, have enough information to know that it is a growing problem in many parts of the country, including Kansas. Recommended practices that minimize risks of nitrate contamination should be given careful and immediate attention.

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Ray E. Leonard
Extension Specialist
Soil Fertility and Management

John Hickman
Extension Specialist
Soil and Water Conservation

G. Morgan Powell
Extension Naturalist
Resource Engineer

COOPERATIVE EXTENSION SERVICE
MANHATTAN, KANSAS

MF-857 April 1987

File Code: Engineering 4-5
Water Resources (quality)