



## Nitrate in Drinking Water

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Nitrate ( $\text{NO}_3$ ) is the primary source of nitrogen (N) for plants; it is a nutrient they cannot live without. Nitrates are naturally occurring in soil and water. Extensive farming can rob the soil of its natural nitrogen source, so farmers often add nitrate fertilizers. Properly managed, nitrogen does not endanger health and can increase crop production. However, when more nitrogen is added to the soil than the plants can use, excess nitrate can leach into groundwater supplies and contaminate wells. On-site sewage systems (such as septic tanks and lagoons) also can be a source of nitrate pollution. Because nitrate is converted to a very toxic substance (nitrite) in the digestive systems of human infants and some livestock, nitrate-contaminated water is a serious problem.

### How does nitrate affect families?

Human babies are extremely susceptible to acute nitrate poisoning because of certain bacteria that may live in their digestive system during the first few months of life. These bacteria change nitrate into toxic nitrite ( $\text{NO}_2$ ). The nitrite reacts with hemoglobin (which carries oxygen to all parts of the body) to form methemoglobin, which does not carry oxygen. The level of oxygen being carried throughout the body decreases in proportion to the amount of hemoglobin converted to methemoglobin. As the oxygen level decreases, the baby is suffocated. This condition is called methemoglobinemia.

The most obvious symptom of nitrate poisoning is a bluish color of the skin, particularly around the eyes and mouth. This is called cyanosis. A baby with these symptoms should be taken to an emergency

medical facility immediately. The doctor will take a blood sample to be sure the baby is suffering from nitrate poisoning. The blood sample of an affected baby is a chocolate brown instead of a healthy red. Nitrate poisoning can be treated, and in most cases the baby makes a full recovery. It is crucial, however, to deal with the problem immediately, because without treatment a baby can die.

Around the age of three months, an increase in the amount of hydrochloric acid in a baby's stomach kills most of the bacteria that convert nitrate to nitrite. By the time a baby is six months old, its digestive system should be fully developed, and none of the nitrate-converting bacteria remain. However, children under one year of age and pregnant women are at risk for adverse effects. In older children and adults, nitrate is absorbed and excreted, and methemoglobinemia is no longer a concern.

### How does nitrate affect livestock?

Ruminant animals (such as cows and sheep) and infant monogastrics (such as baby pigs and chickens) also have nitrate-converting bacteria in their digestive systems. For this reason, nitrate poisoning affects them the same way it affects human babies. Because adult monogastrics generally do not have nitrate-converting bacteria, they are not affected by methemoglobinemia. Horses, however, are an exception. They are monogastric, but they also have a cecum, which is similar to a rumen. The nitrate-converting bacteria living in the cecum increase the risk of nitrate poisoning.

Livestock are exposed to nitrate in feed as well as

in water. Crops harvested after weather stress (such as drought) are especially likely to have high nitrate contents. To protect livestock, fodder can be tested for nitrate before being fed.

The symptoms of nitrate poisoning in animals include a bluish or brownish discoloring of nonpigmented areas (around the mouth and eyes) or mucous membranes, a sluggish, staggering gait, rapid heartbeat, frequent urination and labored breathing followed by collapse. In severe cases, convulsion and coma may occur, followed by death one to three hours after the first signs appear.

A veterinarian should be contacted as soon as any of these symptoms are noticed. Blood for diagnosis must be drawn while the animal is alive or within two hours after death. Blood from affected animals will have a chocolate brown color. If the problem is diagnosed in time, animals can be treated and often fully recover. Pregnant animals that recover may abort within a few days.

## How much nitrate is dangerous?

Drinking water quality standards have been set by the federal government to offer the greatest protection to infants. The standard of ten milligrams per liter (mg/l) nitrate-nitrogen has a small margin of safety built into it. Because of this safety factor, some individuals can drink water exceeding the standard and show no adverse effects. However, levels above this standard are considered to be potentially hazardous.

Currently, there is no regulatory drinking water quality standard for livestock. Researchers suggest a level of 100 mg/l of nitrate-nitrogen. Strong animals may tolerate higher levels, but this level is designed to protect animals that are unhealthy, very young, pregnant or on a low-energy diet. Nitrate levels in feed and forage must also be considered in rations for ruminant animals.

## How does nitrate get into the water?

Nitrate contamination occurs when there is more nitrate in the soil than plants can use and when water can move easily through the soil and underlying rock.

Excess nitrate is harmful to:

| Monogastrics<br>Infants: | Ruminants<br>Infants: |
|--------------------------|-----------------------|
| Humans                   | Sheep                 |
| Chickens                 | Cattle                |
| Pigs                     |                       |
| Horses                   |                       |
| Adults:                  | Adults:               |
| Horses                   | Sheep                 |
|                          | Cattle                |

The excess nitrate is carried through the soil into groundwater supplies by irrigation, rainwater and snowmelt. This occurs particularly where the soil is sandy, gravelly or shallow over porous limestone bedrock. Excess nitrate can accumulate in the soil in several ways.

First, applying more nitrate fertilizer to the soil than a crop can use will build up high levels of nitrate.

Second, manure and sewage contain both ammonia and organic forms of nitrogen. Organic nitrogen may be converted to ammonia in the soil. This ammonia, along with any ammonia fertilizer that is applied, is converted to nitrate by soil bacteria in a process called nitrification. Nitrification is important because plants can only use nitrogen in the nitrate form. However, when more ammonia is nitrified than plants can use, the unused nitrate will accumulate in the soil.

Finally, some plants, soybeans and alfalfa in particular, can take nitrogen out of the air and put it into the ground through their root nodules. This process is called nitrogen fixation. Small amounts of nitrate also enter the soil with rain during electrical storms. Neither process produces contaminating amounts of nitrate on its own, but both should be taken into consideration when determining how much fertilizer is needed.

## How to tell if water is contaminated with nitrate

Because nitrate is colorless, tasteless and odorless, water must be chemically tested to determine if it is contaminated. Many laboratories in Missouri will test private water supplies for nitrate. To have your water tested, you must get a sample container from the laboratory, draw the sample as directed by the lab and get the sample to the lab as quickly as possible to ensure a reliable test. For information on testing labs in your area, contact your local University Outreach and Extension center or local health department.

Accurately determining the nitrate level in a well can be difficult since nitrate levels vary according to the time of year. For this reason, spring is the best time to test, because snowmelt and rains will leach any excess nitrate into the groundwater. A water test done in late fall can be misleading because the well may be temporarily low in nitrate if there have been no heavy rains.

To protect the health of your family and livestock, annual water tests should also be made for bacteria, total dissolved solids and pH.

For more information about water testing, refer to MU publication, WQ 100, *Water Testing: What to Test For*.

If your well has been tested and the report shows that the water is contaminated with high nitrate levels, you must immediately stop feeding it to infants. As alternatives to contaminated water, you can plan to breast feed, feed formula prepared with bottled distilled water or feed pre-mixed infant formula.

The easiest way to deal with a contaminated well is to find a new, clean source of water, such as a spring, a cistern or a new well. In addition, water from farm ponds is usually low in nitrate because algae use nitrate as a nutrient source. If you do not have access to a new water supply, the contaminated water can be treated to remove the nitrate. However, only long-term nitrogen management can prevent further contamination.

## How can nitrates be reduced or removed from water?

Nitrate is a very soluble substance, easily dissolved in water and extremely hard to remove. Treatment for nitrate is, therefore, very complicated and expensive. The three methods of reducing or removing nitrate are: (1) demineralization by distillation or reverse osmosis; (2) ion exchange; and (3) blending.

### Demineralization

Demineralization removes nitrate and all other minerals from the water. Distillation is one of the oldest, most effective types of demineralization. The distilling process has only three steps: (1) the water is boiled; (2) the resulting steam is caught; and (3) the steam is condensed on a cold surface, turning back into water. The nitrate and other minerals remain concentrated in the boiling tank.

Reverse osmosis is another way to demineralize water. It reduces but does not remove all nitrates. In a reverse osmosis system, the water is put under pressure and forced through a membrane that filters out minerals and nitrate. One-half to two-thirds of the water remains behind the membrane as rejected water. The yield of treated water to reject water is related to the amount of pressure applied; the lower the water pressure, the greater the volume of reject water. Higher-yield systems use water pressures in excess of 150 psi. The systems that operate using standard household water pressure (35 to 45 psi) will yield some treated water, but a large amount of untreated water goes down the drain. Household units are usually small enough to fit under the sink or on a kitchen counter.

Both of these demineralization systems require a lot of energy to operate efficiently and are high-main-

tenance systems. They are also low-yield systems that may provide enough water for a family, but cannot produce the large quantities needed for livestock.

### Ion exchange

The second type of water treatment for nitrate contamination is ion exchange. Ion exchange introduces another substance that trades places with the nitrate. Most often chloride is exchanged for nitrate. The ion exchange unit is a tank filled with special resin beads that are charged with chloride. As water containing nitrate flows through the tank, the resin takes up nitrate in exchange for chloride. In time, all the chloride will be exchanged for nitrate. The resin can then be recharged by backwashing with a brine solution (sodium chloride) and reused.

Because ion exchange systems can treat large volumes of water, they are more appropriate than demineralization for treatment of livestock water supplies. There are, however, some drawbacks to ion exchange systems. First, in addition to exchanging nitrate, the resin beads will also take up sulfate in exchange for chloride. Therefore, if sulfates are present in the water supply, the capacity of the resin to take up nitrate is reduced. Second, the resin may also make the water corrosive. For this reason, the water must go through a neutralizing system after going through the ion exchange unit. Finally, backwash brines, which are high in nitrate, must be disposed of properly so they do not re-contaminate the groundwater supply.

### Blending

The third and most common way to reduce nitrates is to dilute the nitrate-polluted water by blending it with water from another source that has low nitrate concentrations. Blending the two waters produces water that is low in nitrate concentration. Blended water is not safe for infants but is frequently used for livestock.

There is no simple way to remove all nitrate from your water. Although it is common to think of boiling, softening or filtration as a means of purifying water, none of these methods reduce nitrate contamination. Boiling water is, in fact, the worst thing to do because it actually concentrates the nitrate. Softening and filtration do nothing at all to remove nitrate.

## How can a water supply be protected from nitrate contamination?

When selecting a new well location, be sure to consider possible sources of contamination. Generally, the farther water travels through soil, the

safer it becomes as contaminants are diluted or filtered out. Nitrate is an exception. It is not filtered out of water by the soil, so a new well must be totally isolated from nitrate leaching to prevent contamination. Because different soils have different filtering abilities, standards for well depths and for distances between wells and contaminants cannot guarantee a safe well. The minimum standards governing on-site sewage systems specified by the Missouri Department of Health or Missouri Department of Natural Resources are intended to provide the minimum distances and standards to protect private groundwater and surface water supplies.

New and existing wells also need to be protected from surface drainage. Barnyard surface runoff, for example, can drain directly into an unprotected well and cause serious contamination. Also, if a well is not properly cased, subsurface drainage can move down beside the well casing and contaminate groundwater. Abandoned wells must also be properly sealed to prevent similar groundwater contamination. For more information on well placement and protection, contact the local health department.

You may also want to request DGLS publication, Missouri Private Well Construction Standards. This is available from the Missouri Department of Natural Resources, Division of Geology and Land Survey, Box 250, Rolla, MO 65401.

Like wells, sinkholes are a direct route to the groundwater. Though they may be located miles away from a well, sinkholes can contribute to groundwater contamination. Garbage, dead animals, chemical containers, leftover chemicals or other forms of waste should never be thrown into a sinkhole or stored where water might drain into a sinkhole. If there are sinkholes on your property, it is very important to make sure they are not used to dump garbage. Sinkholes are favorite dumping grounds and have contaminated several water systems without the landowner being aware of the situation. Before the homeowner installs an on-site sewage system, he or she should consult the Missouri Department of Natural Resources and the health department.

## How can nitrogen be managed?

Since nitrate leaches through the soil into the groundwater, the only way to ensure a safe water supply is to control the application of nitrogen to the surface of the ground. The key to good nitrogen management is to match the nitrogen application to the needs of the crop.

Farmers should not overlook the nutrient value of their livestock manure. Manure has significant nutrient value and should be considered and subtracted

from calculations of fertilizer needs. Manure can reduce fertilizer costs and still provide enough nitrogen for crops, while leaving little nitrate to leach down into the groundwater.

Manure application practices can also affect the leaching of nitrate into the groundwater. For instance, if the manure is applied sooner than the crop can use it, a large portion of the nitrate can be lost by leaching.

To save manure for the best application time, a well-engineered, well-constructed storage unit should be provided. The storage units must be large enough to contain the manure without overflowing and must be properly lined to prevent seepage to the groundwater. For more information about manure storage units and their construction, operation and maintenance, refer to MU Publication WQ 201, *Reduce Environmental Problems With Proper Land Application of Animal Waste*.

## “We've been using this water for years and we're OK”

Water can have nitrate levels that are above the EPA standard and still have no obvious effect on your family. This is not surprising for a number of reasons.

1. Methemoglobinemia only affects infants, young monogastrics and ruminant animals.
2. To protect infants, the water quality standard has a small margin of safety.
3. The symptoms of nitrate poisoning might be confused with those of respiratory problems or illness such as congenital heart disease. A blood test is needed to confirm the condition.
4. Because of the fluctuations in the levels of nitrate from year to year, a safe water supply may become unsafe.

Remember that nitrates are essential nutrients for plant growth. Only when there is too much nitrate in the soil does it become a problem in water. Routine water testing is important to protect the health of both families and animals. If nitrate levels in a water supply exceed the present water quality standard, low-nitrate water must be provided for infants to drink. Nitrogen management, the only long-term solution to nitrate contamination, requires consideration of all aspects of nitrogen use. The problem of nitrate contamination is not a simple one, but it must be faced to protect families, animals and the environment.

## Two ways of reporting nitrate concentrations: Know the difference!

When your report comes back from the lab after the water test, the nitrate concentration can be report-

ed either as nitrate (NO<sub>3</sub>) or as nitrate-nitrogen (NO<sub>3</sub>-N). Be sure you know which reporting system is being used since the acceptable concentrations of each are considerably different. If the lab reports its results as nitrate, the drinking water quality standard is 45 mg/l. If the lab reports its results as nitrate-nitrogen, the drinking water quality standard is 10 mg/l. A milligram per liter (mg/l) is also equal to a part per million (ppm). If you are unsure of how to interpret the report, contact the lab, your local University Outreach and Extension center, or local health department. It is important to check the lab report carefully because the two systems are frequently interchanged.

## For more information

These MU publications provide more information about private water supplies: WQ 100, *Water Testing: What to Test For*; WQ 101, *Understanding Your Water Test Report*; WQ 102, *Bacteria in Drinking Water*; and WQ 104, *Understanding Home Water Treatment Systems*.

## Glossary

**Cyanosis.** A blue color of the skin caused by lack of oxygen.

**Demineralization.** The removal of all minerals from water.

**Hemoglobin.** The chemical in the blood that carries oxygen from the lungs to the different parts of the body.

**Inorganic nitrogen.** Nitrogen in the form of ammonia

and nitrate; available commercially as ammonia gas, urea and ammonium-nitrate fertilizer.

**Leaching.** The movement of materials (such as nitrate) down through the soil with water.

**Methemoglobin.** Formed by nitrate combined with hemoglobin in the blood; does not carry oxygen to body cells.

**Methemoglobinemia.** The presence of methemoglobin in the blood; can be caused by nitrate poisoning; commonly called blue-baby disease.

**Monogastrics.** Animals with only one stomach, such as pigs, horses and chickens.

**Nitrification.** The conversion of ammonia to nitrate by bacteria in the soil.

**Organic nitrogen.** The nitrogen obtained from plant and animal material, such as manure or crop residue.

**Resin.** A man-made, plastic material used in ion exchange systems such as water softeners and nitrate filters.

**Ruminants.** Animals that have a rumen in their digestive system; the bacteria in a rumen convert nitrate to nitrite.

**Water quality standard.** The level of pollutants considered by law to be safe. Standards apply and are enforced for public water supplies.

*For more information,  
please visit the MU Extension web site at:*

[muextension.missouri.edu/xplor/](http://muextension.missouri.edu/xplor/)