Nitrate in Drinking Water

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What Is Nitrate and How Does It Get Into Groundwater?

Nitrate (NO_3) is the primary source of nitrogen (N) for plants, and occurs naturally in soil and water. It is an essential component of all living things. At natural levels, nitrate is not a concern, but when levels of nitrate in water get too high, they can pose a potential health risk to humans and livestock. Sources of excess nitrate in water caused by human activities include fertilizers, on-site sewage systems (such as septic tanks and lagoons), wastewater treatment effluent, animal wastes, industrial wastes, and food processing.

How Does Nitrate Affect Families?

Infants and pregnant or nursing women are particularly susceptible to health problems associated with drinking water that has high levels of nitrate. Human infants aged six months or younger are extremely vulnerable to acute nitrate poisoning. This is because of certain bacteria

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that may live in their digestive system. These bacteria change nitrate into toxic nitrite (NO_2), which reacts with hemoglobin (responsible for carrying oxygen in the blood to vital tissues of the body) to form methemoglobin, which does not carry oxygen. The resulting illness is called methemoglobinemia or "blue baby syndrome." Infants that are bottle-fed formula mixed with well water that is high in nitrate can be especially vulnerable. Children older than six months and adults are not usually at risk of developing methemoglobinemia because their digestive systems are fully developed and can excrete the nitrate.

The most obvious symptom of nitrate poisoning is cyanosis, a bluish discoloration of the skin, particularly around the eyes and mouth, due to insufficient oxygen in the blood. A baby with these symptoms should be taken to an emergency medical facility immediately. The doctor will take a blood sample to determine if the baby is suffering from nitrate poisoning. 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 the condition can be fatal.

There is little information available about the long-term effects of drinking water that has elevated levels of nitrate. Some research suggests that nitrate may play a role in spontaneous miscarriages, thyroid disorders, and birth defects. A potential risk of cancer from nitrate (and nitrite) in water and food has also been reported. However, more studies are needed to verify these links and identify other potential risks.

How Does Nitrate Affect Livestock?

Ruminant animals (such as cows and sheep) and infant monogastric animals (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 monogastrics, 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 content. Many weeds within a pasture may also be problematic, such as pigweed and kochia. 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?

The EPA has set a maximum contaminant level (MCL) of 10 milligrams per liter (mg/L) (10 ppm) nitrate-nitrogen for drinking water to offer the greatest protection to infants. Nitrate-nitrogen refers to the amount of nitrogen in the form of nitrate. Nitrate levels above 10 ppm can present serious health risks to infants and pregnant and nursing women. Some individuals can drink water exceeding the standard and show no adverse effects; however, levels above this standard are considered potentially hazardous.

Currently, there is no regulatory drinking water quality standard for livestock. However, water quality standards for a wide range of minerals and other water quality parameters have been recommended and published. Researchers suggest a maximum level of 100 mg/L (100 ppm) 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. For more information, see NMSU Extension Guide M-112, *Water Quality for Livestock and Poultry* (http://aces.nmsu.edu/pubs/_m/M112.pdf).

How Can I Tell If My 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 New Mexico will test private water supplies for nitrate. The New Mexico Environment Department has two programs that offer free testing of private domestic wells. For more information, visit https://www.env.nm.gov/Water/WaterTesting.html. To have your water tested, you must get a sample container from the laboratory, draw the sample as directed by the lab, and return 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 county Extension office (http://aces.nmsu.edu/county/) or local health department.

Accurately determining the nitrate level in a well can be difficult because nitrate levels vary according to the time of year. For this reason, the best time to test is during periods of irrigation, high rainfall, or snowmelt when leaching of excess nitrate into the groundwater is most likely to occur. 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.

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 water, or feed pre-mixed infant formula.

Understanding Your Laboratory Report: Know the Difference Between the Two Ways Of Reporting Nitrate Concentrations

Laboratory test results report nitrate concentrations in water in one of two ways: either as nitrate-nitrogen (NO_3-N) or as total nitrate (NO_3). Most laboratories report nitrate as nitrate-nitrogen (NO_3-N), which is the amount of nitrogen in the nitrate form. Be sure to check your test report to determine which quantity—NO_3-N or NO_3—is reported. Laboratories report nitrate concentration in water as milligrams per liter (mg/L) or as parts per million (ppm), which are equivalent for drinking water (1 mg/L = 1 ppm).

Depending on which reporting system is being used, the acceptable safety levels of nitrate will be different: 10 mg/L nitrate-nitrogen (NO_3-N) = 44.3 mg/L nitrate (NO_3)

Table 1 shows how to convert between concentrations of nitrate (NO_3) and nitrate-nitrogen (NO_3-N).

Table 1. Multipliers to Convert Between Nitrate (NO_3) and Nitrate-Nitrogen (NO_3-N)

To convert	To	Multiply by
Nitrate (NO_3)	Nitrate-nitrogen (NO_3-N)	0.22
Nitrate-nitrogen (NO_3-N)	Nitrate (NO_3)	4.43

The conversion factor is used because nitrogen makes up 22.5% of the total weight of the nitrate molecule.

If you are unsure of how to interpret the report, contact the laboratory, your local county Extension office, or local health department.

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:

- demineralization by distillation or reverse osmosis
- ion exchange
- blending

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 captured, 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 ratio of treated water to rejected water is related to the amount of pressure applied; the lower the water pressure, the greater the volume of rejected water. Higher-yield systems use water pressures in excess of 150 pounds per square inch (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, and could reduce the efficiency of home septic systems. Household units are usually small enough to fit under the sink or on a kitchen counter.

Both of these demineralization systems require a great deal of energy to operate efficiently and are high-maintenance systems. They are also low-yield systems that may provide enough water for a family, but cannot produce the large quantities needed for livestock.

The second type of water treatment for nitrate contamination is ion exchange. Ion exchange introduces another substance that replaces 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 back washing 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 treating 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.

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 the 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 reduces 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.

It should also be noted that water that is high in nitrates can be safely used for washing, bathing, cleaning dishes, and other uses that do not involve drinking the water.

Visit the Water Quality Association website (WQA; wqa.org) or the National Sanitation Foundation (NSF International; nsf.org) to search for products that are certified to NSF and WQA standards for nitrate reduction. Visit WQA to locate qualified water professionals in your area.

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 New Mexico Environment Department 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 along 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 New Mexico Environment Department or your local county Extension office (http://aces.nmsu.edu/county/). You can also find information on drinking water wells in *New Mexico Farm*A*Syst Fact Sheet #1* (http://aces.nmsu.edu/farmasyst/pdfs/1fact.pdf).

Another important source of excess nitrates in groundwater is leaky on-site sewage systems (septic systems). It is important to maintain septic systems because they can pollute wells when placed too close to a well, when not installed properly, and/or when not maintained. Ensure that the septic tank is cleaned out regularly. For more information on household wastewater treatment, see *New Mexico Farm*A*Syst Fact Sheet #6* (http://aces.nmsu.edu/farmasyst/pdfs/6fact.pdf)

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. Spreading more manure or fertilizers than crops can use can result in groundwater contamination over time. 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.

To save manure for the best application time, you will need a well-engineered, well-constructed storage unit. The storage unit must be large enough to contain the manure without overflowing and must be properly lined to prevent seepage to the groundwater. Manure management systems for large operations are regulated by state and federal environmental agencies. For smaller operations, see *New Mexico Farm*A*Syst Fact Sheet #7* (http://aces.nmsu.edu/farmasyst/pdfs/7fact.pdf) or contact your local county Extension agent (http://aces.nmsu.edu/county/).

"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. There are a number of possible reasons for this:

- Methemoglobinemia only affects infants, young monogastrics, and ruminant animals.

- The EPA maximum contaminant level of 10 ppm was adopted to offer maximum protection to infants, and as such has a small margin of safety factored into it.

- 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.

- 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 maximum safe level, an alternative water source must be provided for infants to drink. Nitrogen management, the only long-term solution to nitrate contamination, requires consideration of all aspects of nitrogen sources. The problem of nitrate contamination is not a simple one, but it must be faced to protect families, animals, and the environment.

Additional Resources

For more information on nitrate and groundwater protection, you can consult the following websites:

http://water.usgs.gov/edu/nitrogen.html
http://water.usgs.gov/nawqa/nutrients/pubs/wcp_v39_no12/
https://www.epa.gov/nutrient-policy-data/estimated-nitrate-concentrations-groundwater-used-drinking
https://www.epa.gov/dwstandardsregulations

For information on private wells and well water treatment:

https://www.water-research.net/index.php/nitrate
http://www.cdc.gov/healthywater/drinking/private/wells/disease/nitrate.html

For information on septic systems and groundwater contamination:

https://www.epa.gov/septic
https://www.epa.gov/sites/production/files/2015-08/documents/mgwc-gwc1.pdf

Glossary

Cyanosis: A blueish discoloration of the skin caused by lack of oxygen.

Demineralization: The removal of all minerals from water.

Inorganic nitrogen: Nitrogen in the form of ammonia and/or 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.

Maximum Contaminant Levels (MCLs): Standards that are set by the United States Environmental Protection Agency (EPA) for drinking water quality. An MCL is the legal threshold limit on the amount of a substance that is allowed in public water systems under the Safe Drinking Water Act.

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 syndrome.

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: An artificial 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.

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