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Quality Water for Idaho

Nitrate and Groundwater

by Robert L. Mahler, Alex Colter, and Ronda Hirnyck

Nearly 95 percent of Idahoans rely on groundwater as their primary source of drinking water. Nationally, groundwater provides about 50 percent of drinking water. Thus, protection of groundwater from contamination by any substance that might cause health problems is a serious concern.

One potential groundwater contaminant is the inorganic chemical nitrate (NO_3). In general, recent surveys in Idaho have found very few rural water wells with nitrate levels higher than the U.S. Public Health Service drinking water standard (table 1).

Table 1. Drinking water guidelines for water with known concentrations of nitrate.

NO_3-N (ppm)	NO_3 (ppm)	Guideline
0 to 10	0 to 44	Safe for humans and livestock
11 to 20	45 to 88	Generally safe for human adults and livestock. Do not use for human infants
21 to 40	89 to 176	Short-term use for human adults acceptable. Short-term use for all livestock is acceptable unless feed sources are high in nitrate. Long-term use poses risk. Do not use for human infants.
41 to 100	177 to 440	Moderate to high risk for human adults. Moderate to high risk for young livestock. Acceptable for mature livestock if feed is low in nitrate. Do not use for human infants.
Over 100	Over 440	Do not use.

Health concerns

Human

Humans ingest nitrate in food and water. In older children and adults, nitrate is ingested, absorbed from the digestive tract, and excreted rapidly in the urine. Healthy human adults can consume fairly large amounts of nitrate with few, if any, known short-term adverse effects. The health effects of chronic, long-term consumption of high levels of nitrate are uncertain. They are the subject of several current research studies.

Blue-baby syndrome. Infants younger than 6 months old are susceptible to nitrate poisoning. Newborn infants have little acid in their digestive tracts for digesting food. Instead, they depend on bacteria present in their digestive tracts at birth to help them digest food. These bacteria also change nitrate to toxic nitrite (NO_2). Generally, by the time infants reach the age of 6 months, hydrochloric acid levels in their stomachs rise and kill most of the bacteria that convert nitrate to nitrite.

Once formed, nitrite enters the baby's bloodstream. There it reacts with hemoglobin, the molecule that carries oxygen in the bloodstream, to form a new compound called methemoglobin. This compound interferes with the blood's ability to carry oxygen. As oxygen levels decrease, babies 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 percent of the hemoglobin has been converted to methemoglobin. Treatment must begin quickly.

Infant deaths from methemoglobinemia, sometimes called "blue baby syndrome," are rare. Some documented deaths have been linked to high levels of nitrate in well water. Doctors now recommend using bottled water to make formula when nitrate-nitrogen levels exceed the U.S. Public Health Service drinking water standard of 10 parts per million (ppm) NO_3-N.

Other possible impacts. Nitrate may also interact with organic compounds (secondary amines) to form N-nitrosamines, which are known to cause cancer. Many organic compounds could link with nitrate to form N-nitrosamines, including some pesticides. This may be important because wells with high nitrate levels are often vulnerable to pesticide contamination. Neither the immediate nor the chronic health effects of N-nitrosamines in humans are well understood.

Livestock

Nitrate poisoning is most likely to occur in ruminant animals such as cattle and sheep. Bacteria in the rumen convert nitrate to toxic nitrite. Monogastric animals such as swine and chickens have no rumen. Most nitrate is rapidly eliminated in their urine.

Although some plants naturally contain potentially harmful levels of nitrate, water rarely does. High-nitrate water is generally a health hazard to animals only when consumed with high-nitrate feeds.

Symptoms of methemoglobinemia in animals include lack of coordination, labored breathing, blue membranes, vomiting, and abortions. Dairy cows may produce less milk without showing any physical symptoms. If animals show signs of nitrate poisoning or you suspect a problem, consult a veterinarian to determine if nitrate is the problem and, if necessary, to administer an antidote.

Water testing

If you suspect nitrate in drinking water used for humans or livestock, start a routine (once a year) water sampling and testing program to monitor nitrate levels. Nitrate is detectable in water only by chemical testing. It is colorless, odorless, and tasteless.

In Idaho, the Department of Environmental Quality, the University of Idaho, the Idaho health districts, and several private testing laboratories can test for nitrate. Check with the UI Extension office in your county for a list of certified private laboratories.

Most laboratories usually report nitrate content in parts per million (ppm) of nitrate-nitrogen (NO_3-N). Occasionally a lab will report results in ppm NO_3. To interpret the results, you must know the form in which they are reported. To convert NO_3-N to NO_3, multiply by 4.4. For example, 10 ppm NO_3-N equals 10 x 4.4 ppm NO_3, or 44 ppm NO_3.

Guidelines for the use of water with known nitrate-nitrogen concentrations are shown in table 1. Water containing less than 10 ppm NO_3-N is considered safe for all humans and livestock. Water containing between 11 and 20 ppm NO_3-N is generally safe for human adults and all livestock; however, it should not be given to human infants. Nitrate-nitrogen concentrations between 21 and 40 ppm may be okay for short-term use by adults, but long-term use may be risky. Water containing more than 40 ppm nitrate-nitrogen should not be used for drinking purposes.

Nitrates in groundwater

Even though naturally occurring and introduced nitrate is a common groundwater contaminant at low concentrations in the United States, the severity of nitrate contamination is hard to assess. Researchers agree that nitrate concentrations in unpolluted groundwater seldom exceed the U.S. Public Health Service 10 ppm NO_3-N standard.

Recent United States Geological Survey data show that almost every state has areas where nitrate levels exceed the standard. However, a recent Environmental Protection Agency study found that only 2.7 percent of rural wells exceeded the standard. In recent studies of rural wells in Idaho, fewer than 5 percent tested exceeded the federal 10 ppm nitrate-nitrogen standard. Several recent studies in the Great Plains and Midwest have found localized areas where nitrate concentrations in groundwater have been increasing. A significant portion of these locations are in agricultural areas where feedlots are common or high rates of nitrogen are used to fertilize crops.

Sources of nitrate in groundwater

Cultivated soil usually contains between 1,500 and 4,000 pounds per acre of nitrogen bound up in living and dead plants and animals. Plants are unable to use this organic nitrogen directly. But as organic matter decomposes, it releases nitrogen in forms plants can use, primarily nitrate (NO_3). This conversion of organic nitrogen into inorganic, plant-available forms occurs in natural ecosystems (forest or grassland, for example) as well as in agriculture.

Organic nitrogen fertilizers used in agriculture include animal manures, human wastes, composts, sewage sludge, legume crops, and green manure crops. The most common inorganic nitrogen fertilizers contain nitrate and/or ammonium (NH_4).

Plants do not necessarily use all the nitrate in chemical fertilizers or all the nitrate produced when organic matter decomposes. When the nitrate supply is greater than the amount plants use, nitrate can accumulate in the soil, be lost from the system, or both. With greater nitrogen inputs for higher crop yields, efficiencies of nitrogen use may be lower and the potential for losses may increase.

Nitrate can be lost from the system in a variety of ways. From the standpoint of groundwater quality, leaching into groundwater is the only concern. Leaching is the downward movement of water and nitrate through the soil. The potential for nitrate leaching varies with soil type and with the amount of water in precipitation or irrigation. For example, sandy soils under high precipitation or irrigation have a high leaching potential.

Downward movement of nitrate through soils was taking place even before the presence of humans; it is unrealistic to expect to stop it entirely. However, careless use of fertilizer and improper management of other nitrogen sources can increase the rate of movement and the magnitude of groundwater contamination. They must be avoided.

In urban areas nitrogen materials are abundant, and the potential for groundwater contamination is high. Nitrogen fertilizers used on lawns, gardens, and golf courses are leachable. The nitrogen in compost and pet droppings can easily leach into groundwater if not carefully managed. Finally, improperly maintained septic systems can result in nitrate contamination of groundwater supplies.

Treatment options for nitrate in drinking water

Nitrate easily dissolves in water, and it is very difficult to remove. If water contains more than 10 ppm (milligrams per liter, or mg/L) of nitrate-nitrogen, the viable options for reducing health risks are drinking water replacement or in-home treatment. Unfortunately, simple household treatment methods for other contaminants—such as boiling, filtration, disinfection, and water softening—are not effective for nitrate removal. Boiling will actually increase the nitrate concentration of the remaining water.

The use of bottled water for cooking and drinking is a relatively inexpensive method for reducing the health risks associated with nitrate intake.

The three in-home water treatment methods that can effectively remove nitrate are distillation, reverse osmosis, and ion exchange. Treatment of drinking water to remove nitrate is expensive. Factors to consider when purchasing a treatment system are the initial purchase price, the cost of regular maintenance, electricity rates, and the quantity of drinking and cooking water desired. Always test your water before purchasing water treatment equipment. The costs, maintenance requirements, and speed of treatment for each of these methods are shown in table 2.

Distillation

Contaminated water is heated to form steam. Nitrate, as well as other inorganic compounds and nonvolatile organic molecules, do not evaporate with the water and are left in the boiling tank. The steam is then cooled and condenses in a separate tank to form clean drinking water.

Large distillers can distill approximately 1/2 gallon per hour. Small units produce roughly 1 quart of water per hour.

Operating costs depend on the particular system and the cost of electricity. Initial costs range from $250 for a small unit to over $1,500 for the largest in-home unit. Electricity consumption makes operating costs higher than the other treatment methods.

Distillers are relatively simple systems but require periodic maintenance to remove scale from the boiling tank. Maintenance intervals vary with the quantity of contaminants in the water and the amount of clean water desired.

Table 2. Comparison of in-home methods for removing nitrate-N from drinking water.

Method	Costs: Initial	Costs: Ongoing	Maintenance	Speed	Comments
Distillation	$250-$1,500	$400-$500 annually plus electricity	Periodic scale removal	4-10 gal/day	Simpler, easier to maintain. Higher electricity costs.
Reverse osmosis	$300-$1,300	$100-$300 annually plus electricity	Filter replacement	2-10 gal/day	Wastewater loss. High maintenance.
Ion exchange	$600-$2,200	$3-$4 per bag of salt	Disposal of backwash brines	Only limited to size of tank	Sodium content in water may be health risk to humans and plants

Reverse osmosis

Reverse osmosis involves the movement of water under pressure through a membrane. The membrane has microscopic openings that allow only water molecules to pass through, leaving behind nitrate and other inorganic chemicals like calcium and magnesium. Unfortunately, reverse osmosis also removes beneficial chemicals, such as fluoride.

The initial cost of a reverse osmosis unit ranges from $300 to $1,300 depending on the amount of water needed. Maintenance costs include periodic replacement of the reverse osmosis membrane.

Ion exchange

Ion exchange introduces another substance, normally chloride, to substitute nitrate in the water. The ion exchange system is a tank filled with special resin beads that are charged with chloride. As contaminated water flows through the tank, the nitrate exchanges with the chloride. The resin can be recharged by backwashing with a sodium chloride solution.

This method is very effective unless the water contains high amounts of sulfate, which may compete with nitrate in the exchange process. In addition, the contaminated water must go through a neutralizing process prior to treatment. Finally, the backwash brines, which are high in nitrates, must be disposed of properly. An ion exchange unit can cost $600 to over $2,200.

Summary

Both nature and people can be responsible for nitrate found in groundwater. Whatever the source of nitrate, we need to be concerned about minimizing its movement into our groundwater. Although we do not have a complete picture of groundwater contamination by nitrate, we do know the problem is growing.

Of the human activities that contribute nitrate, agriculture and human waste disposal are by far the largest sources. Farmers and other individuals can use management practices to minimize the leaching of nitrate from soils without severe economic consequences.

Do not drink water that contains high nitrate-nitrogen levels (greater than 10 parts per million). If you must use this water for drinking, treat it first!

The authors–Robert L. Mahler is a soil scientist and extension water quality specialist in the University of Idaho Department of Plant, Soil and Entomological Sciences. **Alex Colter** is a graduate student in environmental sciences. **Ronda Hirnyck** is the extension pesticide ccoordinator located in Boise (University of Idaho Extension, District II).

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