NebGuide
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Drinking Water: Nitrate-Nitrogen

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University of Nebraska–Lincoln Extension and the Nebraska Department of Health and Human Services place a high priority on water quality and jointly sponsor this series of educational publications.

Nitrate-nitrogen is sometimes present in drinking water. At certain levels it can present a health risk. Properly locating and constructing wells along with regularly testing water can help to manage the risk.

Many Nebraskans have questions about the impact of nitrate in their drinking water. Water quality monitoring shows that nitrate is present in groundwater throughout much of Nebraska and concentrations are increasing in some areas.

Nitrogen is essential for all living things, as it is an essential component of protein. Nitrogen exists in the environment in many forms and changes forms as it moves through the nitrogen cycle. However, excessive concentrations of nitrate-nitrogen in drinking water can be hazardous to health, especially for infants, nursing mothers, and pregnant women.

Sources of Nitrate in Drinking Water

Nitrogen is a nutrient applied for lawn and garden care and crop production to increase productivity. Feedlots, animal yards, septic systems, and other waste treatment systems are additional sources of nitrogen that is carried in waste. Nitrogen occurs naturally in the soil in organic forms from decaying plant and animal residues.

Bacteria in the soil convert various forms of nitrogen to nitrate, a form of nitrogen and oxygen. This is desirable since the majority of the nitrogen used by plants is absorbed in the nitrate form. However, nitrate is highly soluble and readily moves with water through the soil profile. If there is excessive rainfall or over-irrigation, nitrate will drain below the plant's root zone and may eventually reach groundwater.

Nitrate in groundwater may result from point sources such as sewage disposal systems and livestock facilities, from nonpoint sources such as fertilized cropland, parks, golf courses, lawns, and gardens, or from naturally occurring sources of nitrogen. Proper site selection for the location of domestic water wells can reduce potential nitrate contamination of drinking water. Important considerations include a sufficient well depth, an adequate distance from possible contamination sources, and a location upslope from possible contamination sources. Proper well construction and maintenance also reduce the risk of drinking water contamination. See NebGuide G2050 "Protecting Private Drinking Water Supplies: Water Well Location, Construction, Condition, and Management" for more information.

Indications of Nitrate

Nitrate in water is colorless, odorless, and tasteless, which makes it undetectable without laboratory testing.

Potential Health Effects

The U.S. Environmental Protection Agency (EPA) Maximum Contaminant Level (MCL) for nitrate-nitrogen in a public water supply is 10 milligrams per liter (mg/L), sometimes expressed as 10 parts per million (ppm) measured as nitrate-nitrogen (NO_3-N). It is based on acute health effects, specifically the risk of methemoglobinemia (explained below). Acute health effects result from ingesting a contaminant over a short time.

The acute health hazard associated with drinking water with elevated levels of nitrate occurs when bacteria in the digestive system transform nitrate to nitrite. The nitrite reacts with iron in the hemoglobin of red blood cells to form methemoglobin, which lacks the oxygen-carrying ability of hemoglobin. This creates the condition known as methemoglobinemia (sometimes referred to as "blue baby syndrome"), in which blood lacks the ability to carry sufficient oxygen to the individual body cells.

Infants under one year of age have the highest risk of developing methemoglobinemia from consuming water with elevated levels of nitrate. Contributing risk factors include digestive and enzyme systems that are not fully developed. Older persons who have a gastrointestinal system disorder resulting in increased bacteria growth may be at greater risk than the general population. In addition, individuals who have a genetically impaired enzyme system for metabolizing methemoglobin may be at greater risk. The general population has a low risk of developing methemoglobinemia, even when ingesting relatively high levels of nitrate/nitrite.

Historical information on infants with methemoglobinemia suggests that a number of infants with the condition also showed signs of diarrhea, inflammation, and infection of the gastrointestinal track, or protein intolerance. The significance of these factors in regard to methemoglobinemia risk, if any, is not known.

Definitive guidelines for determining susceptibility to methemoglobinemia have not been developed. The EPA has established the regulatory threshold for acute health effects based on best available science. The intake from food, drugs, and other sources also is important and must be considered.

Although the EPA standard was set at 10 mg/L based on acute health effects, questions have been raised regarding possible chronic health effects from consuming water with nitrate at various concentrations. Chronic health effects are those that can occur when a contaminant has been ingested over a long time. Research is limited regarding the possibility of chronic health effects due to long-term ingestion of drinking water with nitrate at various concentrations. However, studies have shown a correlation between long-term ingestion of water with nitrate and increased incidence of certain diseases and cancers. Other studies have shown a correlation between increased birth defects and consumption of drinking water with elevated nitrate while pregnant. While correlations may not prove cause and effect, the possibility of chronic health risk resulting from ingestion of nitrate-nitrogen must be considered. The connections between the level of nitrate in drinking water, volume ingested, duration of exposure, and possible chronic risks are not fully understood.

Note: This publication is not a substitute for professional medical advice. If you have questions or concerns related to potential health effects from consuming water containing nitrate, consult your physician.

Testing

Testing Public Water Supplies

Public water supplies classified as either community or non-community are required to test for nitrate concentration. If water comes from a public water supply, users can contact the water utility to learn about the nitrate level in their water.

Testing Private Water Supplies

Water quality in private wells is not currently regulated by federal or state statutes; thus, the regular testing of a private water supply is not required under state or federal law. If users want to know the concentration of nitrate in a private water supply, they will need to have the water tested for a fee and on a confidential basis.

An initial test of a new water supply is recommended to determine the baseline nitrate concentration in the water source. Activities near a well potentially can contaminate the water supply, changing the nitrate concentration over time. Private drinking water wells should be tested annually to monitor changes in nitrate concentration. In addition, private drinking water wells should be tested any time an infant, pregnant woman, nursing mother, or elderly person begins to use the water supply. These groups are believed to be the most susceptible to nitrate health effects.

Tests to determine the presence of nitrate in drinking water should be done by a laboratory approved for nitrate testing. The Nebraska Department of Health and Human Services (DHHS) approves laboratories to conduct tests for drinking water supplies. This approval means that recognized, standard test and quality control procedures are used. See *Drinking Water: Approved Water Testing Laboratories in Nebraska* (G1614) for a list of approved laboratories and contact information for each.

Some Nebraska Natural Resources Districts (NRDs) may offer assistance or cost-sharing to help well owners with water testing. Individuals can contact their NRD to find out if testing assistance is provided.

Laboratories not specifically approved to test for nitrate may use the same equipment and procedures as approved laboratories. Such laboratories may provide accurate analysis, but there is no independent information about the laboratory's ability to obtain reliable nitrate concentration results.

In addition, a variety of test kits and dip strips are available for nitrate testing outside of a laboratory environment. These might be used for preliminary "screening" and to raise awareness of nitrate issues. When using these tests, users should understand the nature of the test and the accuracy of the test results. While an estimate of nitrate concentration level might be obtained, laboratory analysis is needed for an accurate and reliable nitrate measurement.

To have water tested, private water well owners or users must select a laboratory and obtain a drinking water nitrate test kit from the laboratory. The kit will usually include a pre-preserved sample bottle, an information form, and sampling instructions. The sample bottle for nitrate testing may contain a preservative to prevent any loss of nitrate in the sample. This sample bottle should not be rinsed before filling and should only be used for samples intended for nitrate analysis. It must be used within 90 days to ensure validity of the analysis. The sampling instructions provide information on how to collect the sample. These instructions must be followed carefully to avoid contamination and to obtain a representative sample. The sample must be promptly mailed or delivered to the laboratory along with the completed information form.

Interpreting Test Results

Public Water Supply Test Results

The quality of water supplied by Public Water Systems is regulated by the EPA and the Nebraska DHHS. This includes any well with 15 or more service connections or that regularly serves 25 or more people.

Public drinking water standards established by EPA fall into two categories — Secondary Standards and Primary Standards. Secondary Standards are based on aesthetic factors such as taste, odor, color, corrosivity, foaming, and staining properties of water that may affect the suitability of a water supply for drinking and other domestic uses. Primary Standards are based on health considerations and are designed to protect human health. The EPA has established an enforceable Primary Standard for nitrate in public drinking water supplies.

The EPA Maximum Contaminant Level (MCL) is measured and reported as nitrate-nitrogen, (NO_3-N), which is the amount of nitrogen in the nitrate form. The MCL for nitrate-nitrogen in a public water supply is 10 milligrams per liter (mg/L) which can also be expressed as 10 parts per million (ppm). This drinking water standard was established to protect the health of infants and is based on risk assessment using the best knowledge available.

It is worth noting that the European standard is measured and reported as total nitrate (NO_3) with a maximum allowable level of 40 mg/L or 40 ppm. The two reporting systems can be compared as follows:

1 mg/L nitrate-nitrogen (NO_3-N) = 4.4 mg/L nitrate (NO_3)

Therefore, the U.S. standard of 10 mg/L nitrate-nitrogen would be reported as 44 mg/L nitrate if the European reporting method was used, or the European standard of 40 mg/L nitrate would be reported as 9 mg/L nitrate-nitrogen if the U.S. reporting method was used.

Although not common, a few U.S. laboratories report total nitrate (NO_3) rather than the more commonly used nitrate-nitrogen (NO_3-N) quantity. Because potential health risks are often unknown or hard to predict, many drinking water standards are set at some fraction of the level of "no observed adverse health effects." In general, the greater the uncertainty about potential health effects, the greater the margin of safety built into the standard. In the case of nitrate, there may not be a large safety factor. A 1977 report by the National Academy of Science concluded that "available evidence on the occurrence of methemoglobinemia in infants tends to confirm a value near 10 mg/L nitrate as nitrogen as a maximum no-observed adverse-health-effect level, but there is little margin of safety in this value."

Private Water Supply Test Results

While EPA and Nebraska regulations do not apply to private drinking water wells, users of private drinking water should consider the EPA guideline of 10 ppm nitrate-nitrogen when considering the risk associated with their water supply. If nitrate-nitrogen concentrations are found to be above 10 ppm, private drinking water users might voluntarily try to reduce the nitrate-nitrogen concentration in the water, taking into account health risks, cost, and benefits.

Options

Options for Public Water Supplies

If a test indicates that the nitrate-nitrogen concentration of public water exceeds the standard, the public must be notified and steps must be taken by the water supplier to bring the water into compliance. Often, the treatment may be as simple as blending the water that exceeds the standard with water that has a nitrate-nitrogen concentration less than 10 mg/L such that the average concentration of the delivered water is below the EPA standard. Another option for achieving compliance is water treatment, such as with ion exchange or reverse osmosis, to reduce the nitrate-nitrogen concentration. In some cases, compliance may be achieved by offering bottled water to vulnerable consumers in conjunction with developing a source water protection plan designed to eliminate or reduce the source of contamination. Over time, this should reduce the nitrate-nitrogen concentration in the water supply. Public water systems cannot achieve compliance by supplying bottled water as the only means of addressing high nitrate levels.

The Nebraska DHHS has the responsibility for implementing the federal requirements and can take action toward public water supplies that are not in compliance. This action includes Administrative Orders, a precursor to legal action. DHHS issues a Nitrate Administrative Order to public water systems exceeding 10 ppm twice in a three-quarter period. At any given time, a very small percentage of public water supplies in Nebraska may have a nitrate concentration above 10 ppm, and some systems may be under Administrative Order for noncompliance with the MCL. DHHS requires any public water system exceeding 20 ppm in any sample to discontinue the use of the well and provide alternate safe water to all consumers until the concentration of nitrate is less than 20 ppm for two consecutive quarters.

Options for Private Water Supplies

If nitrate-nitrogen exceeds 10 ppm, users should consider that their water exceeds the EPA MCL for nitrate-nitrogen in drinking water. If nitrate-nitrogen exceeds 20 ppm, users might consider that DHHS takes immediate action toward public water suppliers exceeding this concentration. In either case, users might voluntarily consider an alternative drinking water source or water treatment. Decisions should be based on a nitrate analysis by a reputable laboratory, and after consulting with a physician to help evaluate the level of risk.

It may be possible to obtain a satisfactory alternate water supply by drilling a new well in a different location or a deeper well in a different aquifer, especially if the nitrate contamination is from a point source such as livestock or human waste. If the water supply with high nitrate is coming from a shallow aquifer, there may be an uncontaminated, deeper aquifer protected by a clay layer that prevents the downward movement of the nitrate-contaminated water. A new well should be constructed so surface contamination cannot enter the well. It should be located away from any potential sources of contamination, such as septic systems or feedlots. Consult a Nebraska-licensed, water well professional regarding this option. Another alternate source of water is bottled water that can be purchased in stores or direct from bottling companies. This alternative especially might be considered if the primary concern is water for infant food and drinking.

Drinking water can be treated for nitrate-nitrogen by three treatment methods:

- distillation,
- reverse osmosis, and
- ion exchange.

Home treatment equipment using these processes is available from several manufacturers. **Carbon filters and standard water softeners do not remove nitrate-nitrogen. Merely boiling water does not remove nitrate-nitrogen. Boiling water for an extended time results in evaporation and a decrease in water volume. The nitrate does not evaporate with the water, resulting in an increased nitrate-nitrogen concentration in the remaining volume of water.**

The **distillation process** involves heating the water to boiling and collecting and condensing the steam by means of a coil. This process can remove nearly 100 percent of the nitrate-nitrogen since the nitrate-nitrogen does not volatilize with the steam. For information on this treatment method see NebGuide 1493, *Drinking Water Treatment: Distillation*.

In the **reverse osmosis process**, pressure is applied to water to force it through a semipermeable membrane. As the water passes through, the membrane filters out most of the impurities. This process can remove approximately 85 percent to 95 percent of the nitrate-nitrogen. Actual removal rates may vary, depending on the initial quality of the water, the system pressure, membrane technology, and water temperature. For information on this treatment method see NebGuide 1490, *Drinking Water Treatment: Reverse Osmosis*.

Ion exchange for nitrate-nitrogen removal operates on the same principle as a household water softener. However, for the nitrate-nitrogen removal process, special anion exchange resins are used that exchange chloride ions for nitrate and sulfate ions in the water as it passes through the resin. Since most anion exchange resins have a higher selectivity for sulfate than nitrate, the level of sulfate in the water is an important factor in the efficiency of an ion exchange system for removing nitrate-nitrogen.

Summary

Nitrate can be present in some water sources, most often as a result of point or nonpoint source pollution from fertilizer or human or animal waste. Proper well location and construction are key practices to avoiding nitrate contamination of drinking water. Management practices to reduce the risk of contamination from fertilizers and manure/sewage help keep the water supply safe. Ingesting drinking water containing nitrate-nitrogen can present an acute health risk, especially for infants. Public water supplies must comply with the EPA standard for nitrate-nitrogen of 10 ppm. Management of a private drinking water well for nitrate-nitrogen is determined by the well owner and/or water user. A water test is the only way to determine the nitrate-nitrogen concentration. If public drinking water exceeds the EPA nitrate-nitrogen standard, the utility must inform water users and must take steps to reduce the nitrate-nitrogen concentration. If private drinking water exceeds an acceptable nitrate-nitrogen concentration, choices are to use an alternate water supply or treat the water. An alternate supply may be bottled water or a new well in a different location or aquifer. Water treatment options include distillation, reverse osmosis, or ion exchange.

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