NATURAL RESOURCES
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Nitrate: Health Effects in Drinking Water

by

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Nitrate is one of the most common groundwater contaminants in rural areas. It is regulated in drinking water primarily because excess levels can cause methemoglobinemia, or "blue baby" disease. Although nitrate levels that affect infants do not pose a direct threat to older children and adults, they do indicate the possible presence of other more serious residential or agricultural contaminants, such as bacteria or pesticides.

Nitrate in groundwater originates primarily from fertilizers, septic systems, and manure storage or spreading operations. Fertilizer nitrogen that is not taken up by plants, volatilized, or carried away by surface runoff leaches to the groundwater in the form of nitrate. This not only makes the nitrogen unavailable to crops, but also can elevate the concentration in groundwater above the levels acceptable for drinking water quality. Nitrogen from manure similarly can be lost from fields, barnyards, or storage locations. Septic systems also can elevate groundwater nitrate concentrations because they remove only half of the nitrogen in wastewater, leaving the remaining half to percolate to groundwater.

This bulletin focuses on the health effects of nitrate in drinking water, and another bulletin in this series (Fact sheet 400.04, Groundwater: What It Is and How to Protect It), addresses ways of protecting the quality of groundwater supplies.

What Is Nitrate?

Nitrate is an inorganic compound that occurs under a variety of conditions in the environment, both naturally and synthetically. Nitrate is composed of one atom of nitrogen (N) and three atoms of oxygen (O); the chemical symbol for nitrate is NO3. Nitrite (NO2) can be formed from nitrate by a chemical process called reduction. Nitrate does not normally cause health problems unless it is reduced to nitrite.

Nitrate in drinking water is measured either in terms of the amount of nitrogen present or in terms of both nitrogen and oxygen. The federal standard for nitrate in drinking water is 10 milligrams per liter (10 mg/l) nitrate-N, or 45 mg/l nitrate-NO3. when the oxygen is measured as well as the nitrogen. Unless otherwise specified, nitrate levels usually refer only to the amount of nitrogen present, and the usual standard, therefore, is 10 mg/l.

Short-term exposure to drinking water with a nitrate level at or just above the health standard of 10 mg/l nitrate-N is a potential health problem primarily for infants. Babies consume large quantities of water relative to their body weight, especially if water is used to mix powdered or concentrated formulas or juices. Also, their immature digestive systems are more likely than adult digestive tracts to allow the reduction of nitrate to nitrite. In particular, the presence of nitrite in the digestive tract of newborns can lead to a disease called methemoglobinemia.

Infant Feeding Practices to Minimize Intake of Nitrate and Nitrite

1. Breast feeding. Little if any nitrate gets into breast milk, unless the mother is consuming very large quantities of nitrate. Also, bacterial contamination is not a problem when breast milk is consumed directly.
2. Bottle feeding. Use already diluted liquid formulas or use low-nitrate water to dilute concentrated liquid or powdered formulas. Also, mixed formulas should be kept under refrigeration and used promptly to minimize bacterial reduction of nitrate to nitrite.
3. Vegetables. Since many vegetables are high in nitrate, their consumption should be limited until an infant is 4-6 months old and their digestive tract has sufficiently matured. Your physician can help you decide when to add new foods. Vegetables should always be prepared while fresh and refrigerated promptly after cooking to minimize bacterial activity.

What Is Methemoglobinemia?

Methemoglobinemia is the most significant health problem associated with nitrate in drinking water. Blood contains an iron-based compound called hemoglobin, which carries oxygen. When nitrite is present, hemoglobin can be converted to methemoglobin, which cannot carry oxygen. In the blood of adults, enzymes continually convert methemoglobin back to hemoglobin, and methemoglobin levels normally do not exceed 1 percent. Newborn infants have lower levels of these enzymes, and their methemoglobin level is usually 1 to 2 percent. Anything above that level is considered methemoglobinemia.

Few clearcut symptoms are associated with methemoglobin levels between 1 and 10 percent. At higher levels, symptoms of cyanosis usually appear. Babies with this condition have bluish mucous membranes and may also have digestive and respiratory problems. At methemoglobin levels above 20 to 30 percent, the primary effects result from the blood's severely reduced oxygen-carrying capacity and are referred to as anoxia. At methemoglobin levels around 50 to 70 percent, brain damage or death can occur.

Once diagnosed, methemoglobinemia can be readily reversed, although with anoxia permanent damage may have occurred. Methemoglobinemia can be prevented by restricting consumption of nitrite and nitrate and by limiting the opportunities bacteria have to reduce nitrate in food to nitrite before consumption.

Consuming drinking water with nitrate levels near the drinking water standard does not normally increase the methemoglobin level of humans beyond infancy. Some individuals, however, may have increased susceptibility to methemoglobinemia due to exposure to antioxidant medications and chemicals, or other conditions that may inhibit the body's ability to reconvert methemoglobin to hemoglobin (such as pregnancy or certain rare diseases).

Nitrate in drinking water starts affecting the health of the general populace at levels in the range of 100 to 200 mg/l nitrate-N, but the effect on any given person depends on many factors, including other sources of nitrate and nitrite in the diet. Some of the nitrate consumed can be converted in the body to nitrite, which under appropriate circumstances can combine with amines (portions of protein molecules often found in foods, medications, cigarette smoke, decaying plants, soil, and sometimes water) to form nitrosamines, well- documented cancer-causing substances. So far, the only studies linking nitrate in drinking water with cancer have involved nitrate levels that are quite high (at or above 100-200 mg/l nitrate-N).

What Are the Most Common Sources of Nitrate in People's Diets?

Water with nitrate levels below the health standard usually supplies an almost negligible percentage of an adult's nitrate intake. Eighty to 90 percent of the nitrate most people consume comes from vegetables, but this is unlikely to cause health problems because very little of the nitrate in vegetables is converted to nitrite. Meat products account for less than 10 percent of nitrate in the diet, but 60 to 90 percent of the nitrite consumed. This is primarily because of sodium nitrite added to foods such as hot dogs, bacon, or ham. Fruits, grains, and dairy products contribute almost no nitrate or nitrite to people's diets.

How are Safety Standards for Drinking Water Set?

Congress passed the federal Safe Drinking Water Act in 1974. The U S. Environmental Protection Agency was given responsibility for setting drinking water standards for all the states, and each state became responsible for enforcing these standards. In New York State, the Department of Health regulates all public water supplies serving 25 or more people.

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."

Where Can I Get My Water Tested for Nitrate?

Public water supplies in New York State are tested for nitrate at least annually if the source is surface water and at least once every 3 years if the source is groundwater. If nitrate levels are found at or near the health standard, then tests are run more frequently, and potential sources of the nitrate are investigated. You should be able to get the results of tests for a public water supply from your municipal water department, or your county or regional office of the NYS Department of Health.

If you use a private water supply, there are no routine tests done for nitrate. You can get your water tested for nitrate at a private laboratory for about 10 to 15 dollars. To locate a NYS-certified laboratory in your area that tests for nitrate, you can check with your county Cooperative Extension office or your county or regional health department, or you can look in the Yellow Pages of the phone book under "Laboratories-testing."

Once you have located a laboratory, be sure to ask how to collect, store, and ship the sample. In most cases, the sample should be chilled or frozen and possibly fixed with sulfuric acid to prevent bacteria from changing its original chemical makeup.

How Can I Lower the Nitrate Level in My Current Water Supply?

The best solution is to find an alternative water supply for drinking and cooking water purposes. Another possibility is to try to remove or reduce the source of nitrate contamination, although reduction of nitrate concentrations in your well is unlikely to be immediate. Your county Cooperative Extension office and local or regional Department of Health may be able to assist you in locating and cleaning up contaminant sources.

There are no simple ways to remove nitrate from water in the home. Because nitrate does not evaporate the way chlorine does, boiling, freezing, or letting water stand does not reduce the nitrate level. In fact, boiling water for more than 10 minutes can make the nitrate more concentrated. Boiling water in an aluminum pan may also convert nitrate to nitrite.

Home water-treatment units are generally a limited option. A properly operating distillation system will remove nitrate, but is quite expensive to install and operate and must be adjusted properly. Reverse-osmosis units are another option, but also are expensive to install and operate. Anion-exchange units are relatively inexpensive, but have the serious drawback of being effective for only a short period of time (a matter of months, depending on the contents of the water) before the unit becomes saturated and needs to be recharged. For any treatment unit, frequent water testing is necessary to determine whether the system is still working effectively.

Where Can I Get Low-Nitrate Water?

If your private or public water supply has elevated nitrate levels, then purchasing bottled water is one of your best alternatives. Even in bottled water, nitrate levels can vary considerably. Some states require bottled water companies to have their water tested for nitrate annually. As long as the results are below the state standard, the companies don't have to report the actual levels to the Department of Health, but they should be willing to give exact test results to consumers. In general, distilled or mineral-reduced water is more likely to have low-nitrate levels than spring or mineral water.

Municipal water supplies are another potential source of low nitrate water. City water supplies often come from large lakes or reservoirs where any source of nitrate is likely to be diluted by the large quantity of water.

Hauling your own water from springs, lakes, or streams can be risky, both because of the unknown levels of nitrate and because of the possible presence of other contaminants, especially bacteria. Private wells also present the risk of unknown nitrate levels, but are more likely to have been tested for bacterial contamination.

Risks also are associated with collecting rainwater. Rooftop cisterns often contain lead solder, which can be dissolved by rainwater. Also, rain collected off a roof can contain asbestos or other contaminants from the roofing material.

Alternative water supplies are only as good as their source, their collection method, and their storage. Before using any source of water, find out exactly what the levels of nitrate and bacteria are in that supply. Bacterial contamination is a double problem: it may be responsible for the reduction of nitrate to nitrite; but more importantly, the bacteria themselves can cause illness.

For Further Reading

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