Section A

The nitrate contamination concern

In 1974, the U.S. Congress passed the Safe Drinking Water Act (SDWA). This law required the Environmental Protection Agency (EPA) to determine the level of contaminants in drinking water at which no adverse health effects were likely to occur. Contaminants were defined as any physical, chemical, biological, or radiological substances or matter in water. One of the **contaminants** on the EPA list is nitrate (NO_3). The EPA has set the enforceable regulation for nitrate, referred to as the **maximum contaminant level** (MCL) at **10 mg/L or 10 ppm NO_3-N**.

Contaminants are any physical, chemical, matter, biological, or radiological substances in water.

Maximum Contaminant Level (MCL) is an enforceable regulation that establishes the level of a contaminant at which no adverse health effects are likely to occur.

Nitrate (NO_3) is a naturally occurring inorganic ion and a **nitrogen**-oxygen combination which readily reacts with various organic and inorganic compounds.

Groundwater is water contained in pores of geologic materials that make up the earth's crust.

Methemoglobinemia or "blue baby syndrome" is caused when water or food containing nitrates are ingested and bacteria in the human digestive system convert the nitrate to nitrite. Nitrite reacts with iron in hemoglobin to form methemoglobin which has a reduced oxygen carrying capacity.

Nitrate is a naturally occurring form of nitrogen found in most soils. Nitrate is a colorless, odorless, and tasteless compound and is also one of the most common groundwater contaminants in Nebraska. Though nitrate occurs naturally in some **groundwater**, in most cases levels above 3 ppm result from human activities. Nitrates form when microorganisms break down ammonium fertilizers, decaying plants, manures, or other organic residues involved in crop production systems. Sources of nitrate in water include fertilizers, septic systems, wastewater treatment effluent, animal wastes, mineralization of organic matter, industrial wastes, and food processing wastes. Usually plants take up these nitrates, but sometimes precipitation or irrigation water can leach nitrates out of the crop root zone and into the groundwater.

Health concerns

Several health concerns may be related to the consumption of high nitrate water. The acute health hazard associated with drinking water having elevated levels of nitrate occurs when bacteria in the human 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 individual body cells.

The current 10 ppm standard was set to prevent the occurrence of methemoglobinemia in infants under six months of age. Infants are particularly susceptible if fed formula, due to the volume of water intake relative to their body weight. A much greater question is whether consuming water with various levels of nitrate can have chronic health impacts for adults. While research is limited, correlations have been found between long-term ingestion of water with nitrate and increased incidence of certain diseases and cancers.

Figure A-1 shows the location of wells where nitrate-nitrogen concentrations were documented above 10 ppm, in a recent compilation of sampling results across the state. The Platte Valley stands out, as well as northern Holt County, where most intensive corn production is on sandy soils. However, many wells in South Central Nebraska, as well as a smaller but growing number in other locations, are also beginning to show increasing nitrate-nitrogen concentrations.

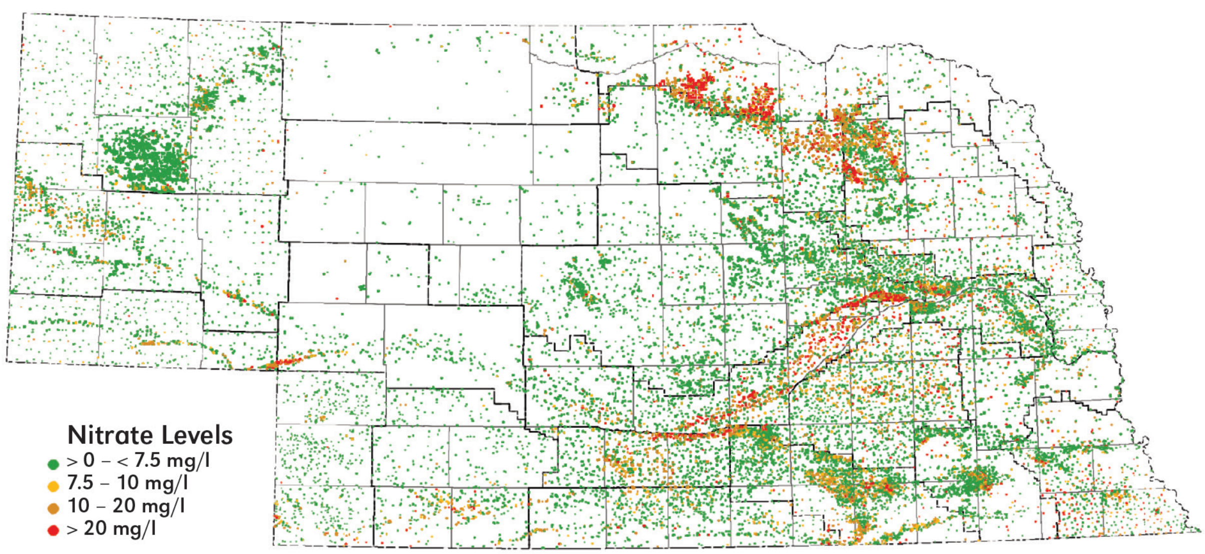

Figure A-1. Nebraska map presenting recorded concentration of nitrate from 1974 - 2012. (Source: Quality-Assessed Agrichemical Database for Nebraska Groundwater, 2013). Empty areas indicate no data reported, not the absence of nitrate in groundwater.

Groundwater sampling programs conducted by local NRDs across the state indicate that groundwater nitrate concentrations continue to rise (*Figure A-2*). However, data for the last 30 years of using nitrogen and irrigation best management practices show signs that some areas in the Platte Valley are seeing nitrate levels plateau or beginning to decline.

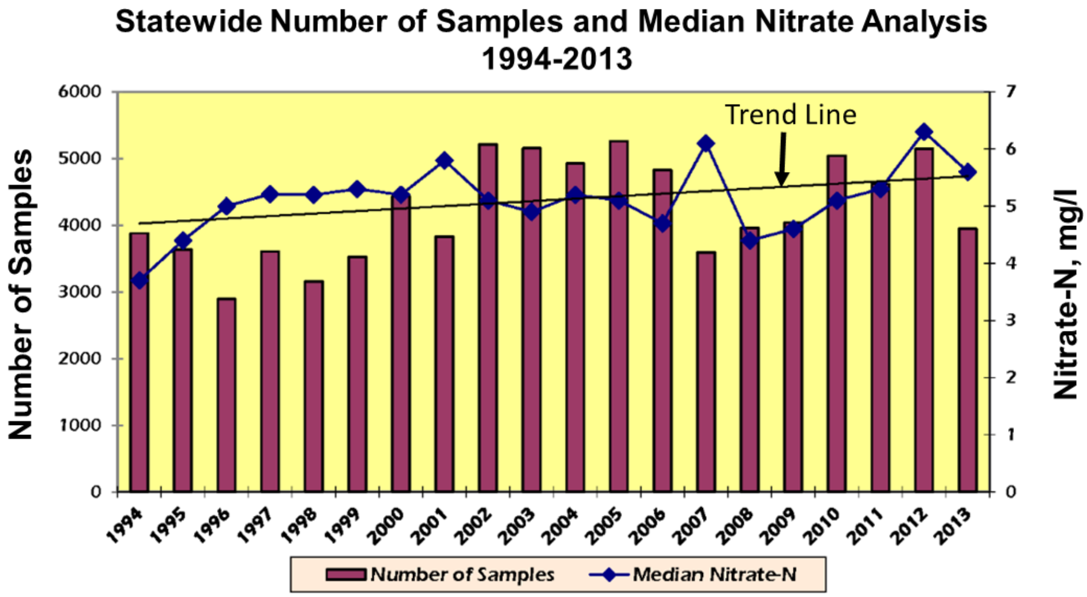

Figure A-2. Water laboratory analyses and median **nitrate-nitrogen** levels for 102,386 samples collected across Nebraska between 1994 and 2013. (See 2014 Nebraska Groundwater Quality Monitoring Report, NDEQ.)

Impacts on town and rural water supplies

Today, residents of cities, small towns, and rural areas deal with excess nitrate concentration in their water supplies. In Nebraska, much (but certainly not all) of the groundwater nitrate is the result of **nonpoint source contamination** coming from intensive production of irrigated corn. Nitrogen leaching loss from applied fertilizer and the spreading of manure is increased by excessive applications of irrigation water. With improper management of nitrogen sources, non-irrigated crop production can also contribute to the problem. In some cases urban sources of contamination, including **nitrate leaching** from areas such as lawns and golf courses, contribute to the nitrate contamination levels. *Figure A-3* depicts the number of cities and towns that have issues with nitrate contamination of their water supplies.

Nitrate-nitrogen (NO_3-N) is one chemical formulation used by the EPA to establish the U.S. drinking water maximum contaminant level for nitrates. 1.0 ppm NO_3-N = 4.5 ppm NO_3.

Nonpoint Source Contamination (NPS) is contamination discharged over a wide land area. Typically the exact source of the contamination is difficult to identify. Leaching of fertilizer from a corn field or surface runoff from a large land area are examples of NPS.

Nitrogen leaching is the passage of nitrogen vertically through the soil to a position where the nitrogen effectively becomes unavailable to the crop.

Figure A-3 shows that at least 12 small towns and villages had to find alternative drinking water supplies and are treating their water to meet the 10 ppm standard. Although the users of private wells are not required to meet the EPA nitrate MCL, they should monitor nitrate levels in the water supply. If nitrate levels are excessive, they should identify an alternative water supply or treat their water to assure it is safe to drink especially if babies will be present.

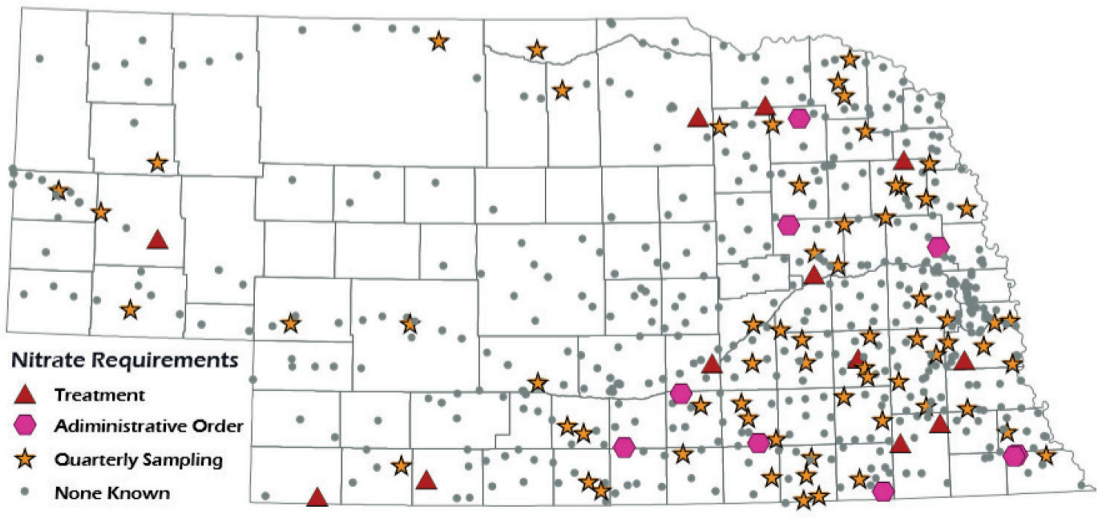

Figure A-3. 2013 map of community and public water supply systems with nitrate contamination issues. (Source: Department of Health and Human Services).

How does nitrate contamination of groundwater happen?

Nitrate contamination happens when water moves through the soil profile that contains excess nitrate (*Figure A-4*). When nitrogen fertilizer, manure, or some other nitrogen source is added to the soil, microorganisms gradually convert the various nitrogen forms to nitrate-nitrogen. Nitrate-nitrogen is highly soluble in water and since soil is a porous system, water passing through the soil will carry some nitrate with it to the groundwater.

One factor is that crops are unable to remove all available nitrogen from the root zone. Even if the crop is under-fertilized, there will be some residual nitrate-nitrogen in the root zone at the end of the growing season. During the off-season, part of the excess nitrate-nitrogen can be leached by excess precipitation. Similarly, early spring precipitation events can move available nitrate-nitrogen from the root zone.

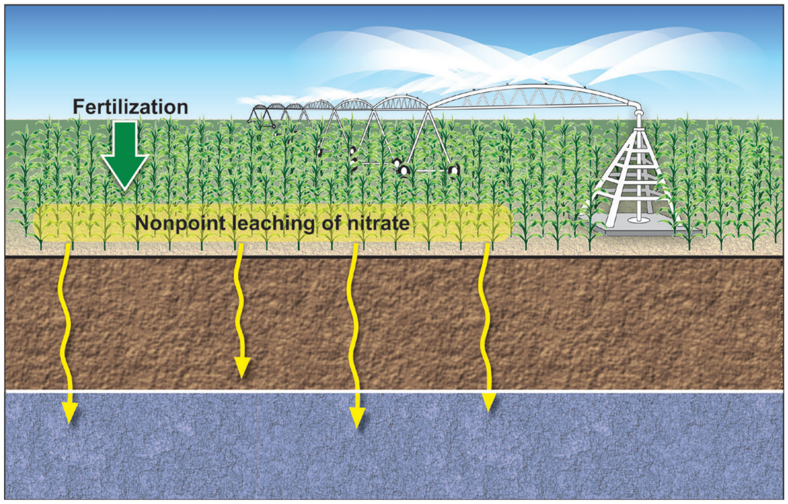

Figure A-4. **Nonpoint source nitrate contamination of groundwater can come from intensive production of irrigated corn.**

At some point, **nitrate leaching** occurs under all corn fields that receive nitrogen fertilizer whether the field is irrigated or not. However, *Figure A-5* shows significant difference in nitrogen leaching potential due to the type of system used to apply irrigation water. *Figure A-5* also shows that nitrate loss cannot be entirely stopped, but it can be reduced with good management. Two major advantages of the surge and sprinkler irrigation systems are that the depth and uniformity of water applied can be more precisely controlled by the irrigator. Center pivots provide the greatest level of control of these two factors. For a traditional furrow irrigation system, the field conditions such as soil texture, cropping practices, and furrow length can contribute greatly to how much water infiltrates into the soil, and thus how uniform the water can be applied along the furrow length.

Nitrate leaching loss rates range from 5 to 10 lb/ac-in of deep percolation or drainage, which is why over-irrigation needs to be avoided.

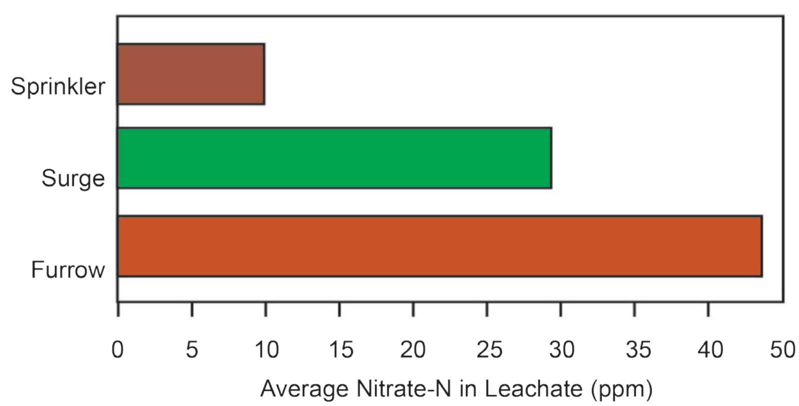

Figure A-5. **Average nitrate-nitrogen concentrations in leachate water below corn fields irrigated by sprinkler, surge flow, and traditional furrow irrigated fields in the Platte Valley. (See Spalding, et al., 2001).**

Annual nitrate leaching losses

University of Nebraska researchers measured water and nitrogen loss from the root zone in a deep, silt loam soils, and sandy soils. Yearly average concentrations of nitrate-nitrogen in the drainage often ranged from 22 to 44 ppm. They found annual nitrate-nitrogen losses ranging from 40 to 80 lb/acre. This occurred with an average of 8 in/yr of drainage from the bottom of the root zone. This amounts to 5 to 10 lb/acre of nitrogen loss per inch of drainage. This rate of drainage is typical under continuous corn production, when following recommended nitrogen and irrigation water management programs. Thus, losses are greater where irrigation and nitrogen applications are not well managed during the growing season.

Aquifer is a water-bearing geological formation capable of yielding water in sufficient quantity to support a well.

Transit time is the length of time required for contaminants to move from the bottom of the root zone to groundwater. Transit times range between a few weeks to decades depending on the depth and texture of the soil.

How long does it take for nitrate contamination of an aquifer to occur?

The time it takes soil nitrate to reach the groundwater **aquifer** after it moves below the root zone is called the **transit time**. Depending on the geology of the area and the depth of drainage loss, nitrate-nitrogen can reach the top of a shallow aquifer in a matter of weeks, or at most, a few months. Today the nitrate problem is appearing in areas where the water table is 100 ft or more below the surface and is covered almost entirely with fine-textured soil material. Some people thought that the depth to groundwater conditions would prevent aquifer contamination. However, nitrate-nitrogen moves slowly in such materials, too. In this case the travel time from the root zone to the water table may be more than 30 years. Some areas in Nebraska have subsoil conditions that greatly limit the movement of nitrate to the aquifer. Groundwater in these areas is not significantly affected by farming practices.

See these publications for additional information:

EC91-735, The impact of nitrogen and irrigation management and vadose zone conditions on groundwater contamination by nitrate-nitrogen (archived publication)

RP189, Agricultural nitrogen management for water quality protection in the midwest

For More Information

Nebraska Department of Environmental Quality. 2014. 2014 Nebraska groundwater quality monitoring report. Prepared Pursuant to Nebraska Rev. Stat. §46-1304.

Spalding, R. F., D. G. Watts, J.S. Schepers, M. E. Burbach, and M. E. Exner. 2001. Controlling nitrate leaching in irrigated agriculture. Journal of Environmental Quality 30: 1184-1194.