



NITRATE IN DRINKING WATER: A Public Health Concern For All Iowans

Executive Summary



Elevated nitrate levels in Iowa's water have been a source of concern in recent decades since the state was identified as a top contributor of the nitrate and phosphorus pollution fueling the Dead Zone in the Gulf of Mexico. Recently, the challenges presented by high levels of nitrate in drinking water sources have received increased attention due to the Des Moines Water Works' suit against three drainage districts in northwest Iowa, an area identified as a hot spot for nitrate pollution in the state and the Nation.

Blue-baby syndrome, a serious and potentially fatal condition that can occur in infants who ingest water in formula containing high levels of nitrate, has long been acknowledged as a health threat. However, recent studies suggest that the health risks associated with nitrate in drinking water go beyond blue-baby syndrome. The Iowa Environmental Council report "Nitrate in Drinking Water: A Public Health Concern for All Iowans" provides an overview of research findings that suggest associations between elevated levels of nitrate in drinking water and human health problems, and calls for action to protect our state's drinking water sources and collective health.

Health Risks Posed by Nitrate in Drinking Water

The U.S. Environmental Protection Agency drinking water standard of 10 milligrams per liter (mg/L) of nitrate-nitrogen (nitrate-N) was established in 1962 to prevent methemoglobinemia, or blue-baby syndrome, a life-threatening condition that decreases the blood's ability to carry vital oxygen through the body. Blue-baby syndrome is rare – especially since establishment of the EPA health standard that regulates public water supplies. As such, some are calling upon the agency to consider raising the allowable nitrate level, claiming that the drinking water standard is unnecessarily stringent.

However, a number of studies suggest links between elevated nitrate concentrations in drinking water and other health issues, including birth defects, cancers, thyroid problems and a variety of other health concerns. Most of these associations have been found when

nitrate levels are higher than the drinking water standard, though some research suggests that nitrate concentrations even lower than the drinking water standard may be harmful.

When nitrate is consumed, it is reduced within the body to nitrite, which is considered unsafe at much lower levels than nitrate. Nitrite is further reduced in the body to N-nitroso compounds that are widely considered to cause cancer and contribute to a variety of health problems.

Iowans are particularly vulnerable to the potential health impacts from nitrate pollution because concentrations of nitrate in Iowa's streams and groundwater have been found to rank among the highest in the U.S., even higher than elsewhere in the Corn Belt and Northern Great Plains. This presents a significant challenge for public drinking water suppliers that are legally required to provide water with nitrate-N concentrations at or below 10 mg/L. In addition, many Iowans rely on private wells

that are unregulated and often untested. These lowans are at a greater risk of ingesting elevated concentrations of nitrate or other regulated pollutants.

“Nitrate in Drinking Water: A Public Health Concern for All lowans” summarizes peer-reviewed literature conducted by a wide variety of respected institutions in the United States and abroad, as well as reports from agencies and other information. Many of the studies referenced in the paper gathered detailed information on large “cohorts,” or study groups, followed over years or even decades. Such long-term research of human subjects is very challenging. Investigators must attempt to sort out many influences: Exposure to nitrate and nitrite comes from drinking water, and also from some foods, cigarette smoke and drugs that contain nitrogen-based compounds. Much of the research suggests that nitrate consumption in drinking water is most problematic when combined with regular exposure to these other sources of nitrate and nitrite and/or other suspect substances, such as some agricultural chemicals. We focus on adverse health outcomes that multiple studies have significantly associated with nitrate intake from drinking water.

- **BIRTH DEFECTS:** Studies conducted in Iowa, Texas, Canada and Australia found statistically significant links between elevated nitrate in drinking water and neural tube defects of the brain and spinal cord, including spina bifida, some oral cleft defects and limb deficiencies.
- **BLADDER CANCER:** Researchers who followed a large group of postmenopausal women in Iowa over many years found an increased risk for bladder cancer as nitrate concentration in water supplies increased. Other likely influences, including exposure to nitrate and nitrite through dietary and other sources, were also considered. Studies in Spain, Germany and Taiwan reported similar findings.
- **THYROID CANCER:** One of the most rapidly increasing cancers in the United States, thyroid cancer, has also been associated with extended exposure to high nitrate levels in drinking water in two large U.S. studies.

Taking Action

While more research is needed to better determine the risks of nitrate exposure, the Iowa Environmental Council asserts that the potential health concerns from nitrate in drinking water provide compelling reasons to act now to reduce pollution and improve water quality.

Drinking water treatment helps us manage the nitrate pollution, but it does not solve the problem. Heightened attention and additional resources are needed to prevent nitrate pollution at the source.

Solving Iowa’s nitrate problem will take time and require a statewide watershed approach that brings urban and rural citizens together to set goals and priorities. Iowa’s Nutrient Reduction Strategy (INRS) is a valuable “toolbox” that offers sound, science-based options to prevent and treat nitrate and phosphorus pollution. However, to adopt the large-scale, long-term conservation efforts called for in the INRS, a sustainable source of funding that is immediate, permanent and substantial, with clear timelines and accountability measures, is required.

The Iowa Environmental Council applauds all those who are taking responsibility to help clean up our water, including farmers, urban landowners, businesses, agency leaders and legislators, but additional participation and leadership is needed. We encourage all lowans to join in this undertaking to benefit the health and well-being of our families, neighbors and those downstream.

To download the full report, visit the Iowa Environmental Council’s website, iaenvironment.org.

NITRATE IN DRINKING WATER: A Public Health Concern For All Iowans

Iowa Environmental Council White Paper



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Introduction

Concerns over elevated nitrate levels in Iowa's water have been raised for a number of reasons in recent decades. Reasons for concern include research showing Iowa is a top contributor of the nutrient pollution (nitrate and phosphorus) that fuels the Dead Zone in the Gulf of Mexico. More recently, the challenges of maintaining nitrate in drinking water at levels that meet health standards have received increased attention due to the Des Moines Water Works' suit against three drainage districts in northwest Iowa, an area identified as a hot spot for nitrate pollution in the state and the Nation.

The U.S. Environmental Protection Agency drinking water standard of 10 milligrams per liter (mg/L) of nitrate-nitrogen (nitrate-N) was established in 1962 to prevent methemoglobinemia, or blue-baby syndrome, a serious and potentially life-threatening condition that decreases the blood's ability to carry vital oxygen through the body. Reported cases have generally occurred in infants under three months of age who have consumed water in formula containing nitrate at concentrations higher than 22 mg/L nitrate-N.¹ Blue-baby syndrome is rare – especially since health standards for nitrate were established for public water supplies. As such, some are calling upon the agency to consider raising the allowable nitrate level, claiming the drinking water standard is unnecessarily stringent.

Many people, however, have not been aware that the health risks of nitrate in drinking water go beyond blue-baby syndrome. Research from Iowa and around the world has associated a number of human health problems, including birth defects and cancers, with elevated levels of nitrate in drinking water. In this paper, the Iowa Environmental Council (IEC) reviews some of the most compelling research relating to these broader public health risks and summarizes the status of nitrate in the state's drinking water supplies. The report concludes with recommendations that range from the political to the practical for "Taking Action" to care for individual and collective health.

Standard for Nitrate in Drinking Water

The drinking water standard for nitrate, set by the U.S. Environmental Protection Agency, can be expressed in different measurements, which are equivalent:

- 10 milligrams per liter (mg/L) as nitrate-nitrogen, or nitrate-N – the same as 10 parts per million (ppm) nitrate-N. This is the method of measurement used in Iowa for drinking water reporting.
- 45 milligrams per liter (mg/L) as total nitrate, or NO₃ – the same as 45 parts per million (ppm) total nitrate, or NO₃.

Most scientific studies reviewed use the measurement of nitrate-N. In this paper, IEC uses nitrate-N as the basis for measurement when specific concentrations are discussed.

Health Concerns

Analyses of animal research and human epidemiological studies suggest links between elevated nitrate concentrations in drinking water and several birth defects, cancers, thyroid problems and a variety of other health concerns.^{2, 3} Most of these associations have been found when nitrate levels are higher than the drinking water standard. However, some research suggests that nitrate concentrations even lower than the drinking water standard may be harmful when there is long-term, chronic exposure and/or when an individual's health situation makes them more susceptible to adverse effects.^{4, 5} Also, while public water supplies are required to provide water that meets drinking water standards, private wells are seldom tested on a regular basis and may contain concentrations of nitrate that exceed the standards.

Nitrate *per se* has not been directly considered to pose a serious health risk unless it is consumed. When nitrate is ingested, it is reduced within the body to nitrite, which is unsafe at levels much lower than nitrate (the drinking water standard for nitrite is 1 mg/L). Then, nitrite is further reduced in the body to N-nitroso compounds (NOCs) through a variety of complex reactions. NOCs are widely considered to be carcinogenic and to contribute to a variety of health problems.^{6, 7}

Scientists know that NOCs can cause mutations and cancerous tumors in *developed* cells and organs.⁸ Similar processes are also thought to affect *developing* cells and organ systems. Links between nitrate and birth defects were first identified in animal studies. This review focuses on human-based, epidemiological studies.

Many of the human studies have been prompted from findings from animal studies.^{1, 9, 10} For example, animal studies have found adverse reproductive effects from ingestion of elevated doses of nitrate and/or nitrite

that have also been found in a number of human epidemiological studies.¹¹ A review of research by Guillette and Edwards (2004), outlined an array of studies that report on effects of elevated nitrate levels on a variety of species, with impacts ranging from subtle changes in physiology and development to mortality.¹²

This report focuses on adverse health outcomes that are most strongly associated with nitrate intake from drinking water, including a number of major structural birth defects and bladder and thyroid cancers. Examples of these studies are detailed in subsequent sections of this paper. Other studies not included in this review suggest nitrate consumption might also be associated with a number of other cancers,^{13, 14} as well as reproductive problems and thyroid disease,¹⁵ macular degeneration,¹⁶ and other health problems.¹⁷ Studies supporting these findings are not included in this review because confirmation studies are more limited and/or mixed in their conclusions. Scientists widely agree that more study is needed.

For this report, IEC reviewed peer-reviewed literature conducted by a wide variety of respected institutions in the United States and abroad, as well as reports from other agencies and information sources. Many of the studies referenced in this paper gathered detailed information on large "cohorts," study groups followed over a number of years or even decades. Such long-term research of human subjects is very challenging. Investigators must attempt to sort out many influences: Exposure to nitrate and nitrite comes from drinking water, and also from some vegetables, processed meats, cigarette smoke and a variety of drugs that contain "nitrosatable," or nitrogen-based, compounds. Much of the research suggests that nitrate consumption in drinking water is most problematic when combined with regular exposure to these other sources of nitrate and nitrite and/or other suspect substances, such as some agricultural chemicals.¹¹

Some vegetables, especially leafy greens, are natural sources of dietary nitrate and nitrite. However, the form of consumption appears to be important. In most studies, the effect of nitrate/nitrite found in vegetables did not seem to be associated with health problems and more often, conveyed health benefits, thought to be from beneficial compounds they contain, such as Vitamin C.¹⁸



Nitrate in Drinking Water

The contamination of municipal and private wells and surface water by nitrate has been documented in many areas of the U.S.¹⁹ Nitrate pollution comes from urban and rural sources that include fertilizers used on crop fields and lawns, leaking septic tanks, wastewater treatment systems, livestock manure and soil tillage. Iowans are particularly vulnerable to health impacts from nitrate pollution because concentrations of nitrate in Iowa's streams and groundwater has been found to rank among the highest in the U.S., even higher than elsewhere in the Corn Belt and Northern Great Plains.²⁰

Many Iowans use public drinking water supplies that are legally required to provide water with nitrate-N concentrations at or below 10 mg/L. Public water supplies are required to regularly report their testing frequency and results to the state. These drinking water reports, often called consumer confidence reports, are regularly provided in various formats or can be requested from the local drinking water utility.

In Iowa, 11 public water supplies – including municipalities, rural water districts, churches, residential care facilities and mobile home parks – exceeded federal safe drinking limits for nitrate or nitrite during 2015, according to the Iowa Department of Natural Resources annual drinking water compliance report.²¹ A 2015 *Des Moines Register* article reported that 60 Iowa cities and towns have battled high nitrate levels in their drinking water over a five-year period, and that 260 cities and towns – about 30 percent of the state's 880 municipal water systems – were considered to be “highly susceptible of becoming contaminated by nitrates and pollutants,” based on information from the Iowa Department of Natural Resources.²² Treatment to correct these problems is expensive.

Not all Iowans use public water supplies or have that option, especially those who live in rural areas. Many residents rely on private wells that are unregulated and often untested. Therefore, people who use private wells for their water supply may be at a greater risk of ingesting elevated concentrations of nitrate or other regulated pollutants. Iowa county-level data on nitrate and other pollutants measured in private well tests can be found at the Iowa Department of Public Health website, at <https://pht.idph.state.ia.us/Environment/PrivateWellWater/Pages/default.aspx>.

A State-Wide Rural Well-Water Survey (Phase 2) conducted from May 2006 to December 2008 found that 12 percent of the private well water samples had nitrate-N at or above the drinking water standard of 10 mg/L.²³ A recent study modeling groundwater nitrate concentrations in private wells in Iowa found that, out of 179 variables studied, well depth, slope length near the well, year the water sample was taken, and distance to the nearest animal feeding operation, were the most predictive of high nitrate levels.²⁴

Studies on Birth Defects

A number of epidemiologic studies have suggested an association between reproductive problems, including several birth defects due to exposure of pregnant women to elevated nitrate in drinking water, which may exacerbate the potentially harmful effects of other pollutants, such as the pesticides atrazine and aldicarb, and naturally occurring arsenic.^{25, 26}

- A 2013 study of 3,300 case mothers and 1,121 control mothers in Iowa and Texas from 1997-2005 found that prenatal nitrate intake in the mother's drinking water was significantly positively associated with offspring diagnosed with neural tube defects of the brain and spinal cord, including spina bifida, some oral cleft defects and limb deficiencies.²⁷
- A 2014 Canadian study found occurrence of congenital anomalies was significantly correlated with concentrations of nitrate in public and private sources of drinking water below the 10 mg/L Canadian drinking water standard, after controlling for intake of folic acid supplements (which are thought to improve reproductive health outcomes).²⁸
- A 2004 study of neural tube defects (NTDs) among babies of Mexican-American women found that exposure to nitrosatable drugs was associated with the defects among women who had high dietary intake of nitrite. In addition, women whose drinking water nitrates measured 3.5 mg/L or greater were 1.9 times more likely to have an NTD-affected pregnancy than women with lower levels of nitrate in their water.²⁹
- A 1984 study from rural Australia investigated the relationship between the mother's drinking water source and birth defects in their children, prompted by a statistically significant, localized increase in congenital central nervous system deformities. The



study found that women who consumed principally groundwater during pregnancy had a significantly increased risk of bearing a child with malformations of the central nervous system and musculoskeletal system, compared with women who drank only rainwater. Analysis of the data by estimated water nitrate-N concentration showed a nearly threefold increase in risk for women who drank water containing 5-15 mg/L of nitrate and a fourfold increase in risk for those consuming water with 15 mg/L or greater nitrate. A seasonal gradient in risk was also evident among groundwater consumers: Risks were much higher for spring and summer conceptions when nitrate levels would tend to rise due to seasonal increases in rainfall and related runoff or leaching of nitrate into water supplies.³⁰

Studies on Bladder Cancer

Some research has linked high concentrations of nitrate in drinking water to urinary bladder cancer. According to the American Cancer Society, bladder cancer accounts for about five percent of all new cancers in the US. It is the fourth most common cancer in men and less common in women.³¹ Incidence rates of bladder cancer in the U.S. increased between 1969 and 1990³² though rates have stabilized more recently. Iowa's incidence rates have been trending slightly above the national average.³³

- A 2016 study followed the health of about 35,000 postmenopausal women who participated in the

Iowa Women's Health Study from 1986-2010. The researchers found a higher prevalence of bladder cancer among those exposed to water with greater than 5 mg/L of nitrate-N for four or more years, compared to women with no comparable exposure. The research analyzed a variety of potential risks and beneficial factors, including diet and vitamin usage. Smoking, in combination with nitrate, was found to increase the risk of bladder cancer. Several other possible influences, including exposure to trihalomethanes, a water pollutant byproduct that results from chlorination processes, were not found to be associated with bladder cancer, nor was diet or Vitamin C intake, which is thought to inhibit formation of harmful N-nitroso compounds in the body.³⁴

- A 2001 study looked at municipal drinking water nitrate concentrations and cancer risk among about 22,000 older women in the Iowa Women's Health Study who had used the same water supply over 10 years. The research found an increased risk for bladder cancer as nitrate concentration in water supplies increased. Women whose average drinking water nitrate exposure level was greater than 2.46 mg/L – considerably lower than the drinking water standard – were almost three times as likely to develop bladder cancer than women who had the lowest nitrate exposure levels (less than 0.36 mg/L).³⁵
- A 2015 study of bladder cancer in Spain that looked at cases from 1998-2001 reported an increased risk of bladder cancer among subjects with the longest exposure to high levels of nitrate (at or above 9.5 mg/L) in drinking water. Lower levels of nitrate in drinking water were found to be inconsistently associated with risk of bladder cancer.³⁶
- A 2005 study in Germany analyzed cancer rates of two groups that were exposed to significantly different levels of nitrate in drinking water over a number of years. The research found a strong correlation

between higher nitrate exposure and increased urothelial bladder cancers in both men and women, though there was higher incidence in men.³⁷

- A 2007 study in Taiwan investigated the association between bladder cancer mortality and nitrate exposure from drinking water. Those with high nitrate levels in their drinking water were 1.76 to 1.96 more likely to die from bladder cancer than those who had the lowest exposure.³⁸

Studies on Thyroid Cancer

According to the American Cancer Society, thyroid cancer is the most rapidly increasing cancer in the United States, where it has tripled in the past three decades. Part of this increase is attributed to more sophisticated diagnostic techniques. Thyroid cancer is commonly diagnosed at a younger age than many other cancers: about two percent of thyroid cancers occur in children and teens.³⁹

- A 2010 National Cancer Institute analysis of the Iowa Women's Health Study (approximately 22,000 women who used the same water supply over 10 years) found an increased risk of thyroid cancer for those women with higher average nitrate levels in public water supplies and with longer duration of consumption of water exceeding 5 mg/L nitrate-N. Greater dietary intake of nitrate was also associated with increased risk of thyroid cancer in this study.⁴⁰
- A 2010 study by the National Institutes of Health and American Association of Retired Persons included a large study group of more than 490,000 men and women to better understand the growing rates of thyroid cancer. The study evaluated overall dietary nitrate and nitrite intake and followed the group for an average of seven years. Among men, increasing nitrate intake was positively associated with thyroid cancer risk, though the study did not find a similar association for women.⁴¹



Photo courtesy of USDA Natural Resources Conservation Service.

Taking Action

The public health research cited in this paper suggests the health impacts of nitrate pollution go beyond blue-baby syndrome to include other serious health concerns. These studies indicate that the real human and economic costs may include serious adverse health complications, disease, increased health care costs and lost productivity. These costs should be weighed seriously as we consider the benefits of allocating additional public and private resources to prevent and treat nitrate pollution.

While more research is needed to better determine the risks of nitrate exposure, the IEC asserts that, based on the current information available, the potential health concerns from nitrate in drinking water provide compelling reasons to act now to reduce pollution and improve water quality in Iowa. Additionally, we have also concluded it would be unwise to weaken the drinking water standard for nitrate at this time.

Drinking water treatment helps manage the nitrate pollution for the short term, but it does not solve the problem. Heightened attention and additional resources are needed to prevent nitrate pollution at the source.

Of course, solving Iowa's nitrate problems will take time. It will require a statewide watershed approach that brings urban and rural citizens together to set goals and priorities. Iowa's Nutrient Reduction Strategy (INRS) is a valuable "toolbox" that offers sound, science-based options to prevent and treat nitrate and phosphorus pollution. Achieving the pollution reduction goals set forth in the INRS will require a long-term commitment.⁴² To realize the conservation efforts called for in the INRS on the scale needed, will require a sustainable source of funding that is immediate, permanent and substantial, with clear timelines and accountability measures.⁴³

IEC encourages Iowans to stay informed about the nitrate levels in their drinking water. Those who receive their water from a public supply can contact their utility to request a copy of its annual water quality status report or obtain local drinking water information and consumer confidence reports at the U.S. EPA website.⁴⁴

Those who get their drinking water from a private well should have their water tested regularly. Low-cost or free testing with consultation is available through many county health departments. Where water has elevated nitrate levels, another water source for drinking water may be advisable while seeking to resolve the problem. Individuals may also want to consult with their health provider about possible ways to mitigate health risks linked to elevated nitrate levels.

Home Treatment to Remove Nitrate in Drinking Water

If drinking water is found to have high nitrate levels, there are a variety of home water treatment options available. Less expensive water filters generally do not remove nitrate, but some treatments such as reverse osmosis, ion exchange or distillation can be effective. While these processes can be expensive and are not always practical to install in a given location, they might be an option, especially for those who are pregnant or planning to start a family, or have a vulnerable immune system.

More information on home water treatment systems can be found in the publication, "Well Water Quality and Home Treatment Systems" published by the University of Iowa State Hygienic Laboratory, at <http://www.shl.uiowa.edu/env/privatewell/homewater.pdf>.



Note: The use of reverse osmosis systems may remove fluoride, which at optimal levels is an effective measure for preventing tooth decay.

Boiling water will not remove nitrate and can actually increase nitrate concentrations. Bottled water is not necessarily lower in nitrate or other pollutants. If bottled drinking water is required, consumers are advised to look for Food and Drug Administration-approved water with low levels of nitrate clearly listed on the label.

Individual Iowans *can* make a difference as advocates for Iowa's water. IEC encourages all Iowans to contact their elected officials to express their concerns about Iowa's drinking water resources. Ask them to:

- Take urgent action to address all sources of nitrate pollution on the scale needed to solve this problem.
- Support organizations that work for clean water and strong public health initiatives.
- Support monitoring efforts so the public can stay informed of water quality trends and areas of concern.
- Support funding for more research on the health impacts of nitrate and other pollutants.

The growing understanding of the health concerns from nitrate pollution of drinking water supplies provides a compelling reason to take actions now to protect and improve our water quality.

IEC applauds all those who are taking responsibility to help clean up our water, including farmers, urban landowners, businesses, agency leaders, legislators and others. We encourage all Iowans to join in this undertaking to benefit the health and well-being of our families, neighbors and those downstream.

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Endnotes and Links

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