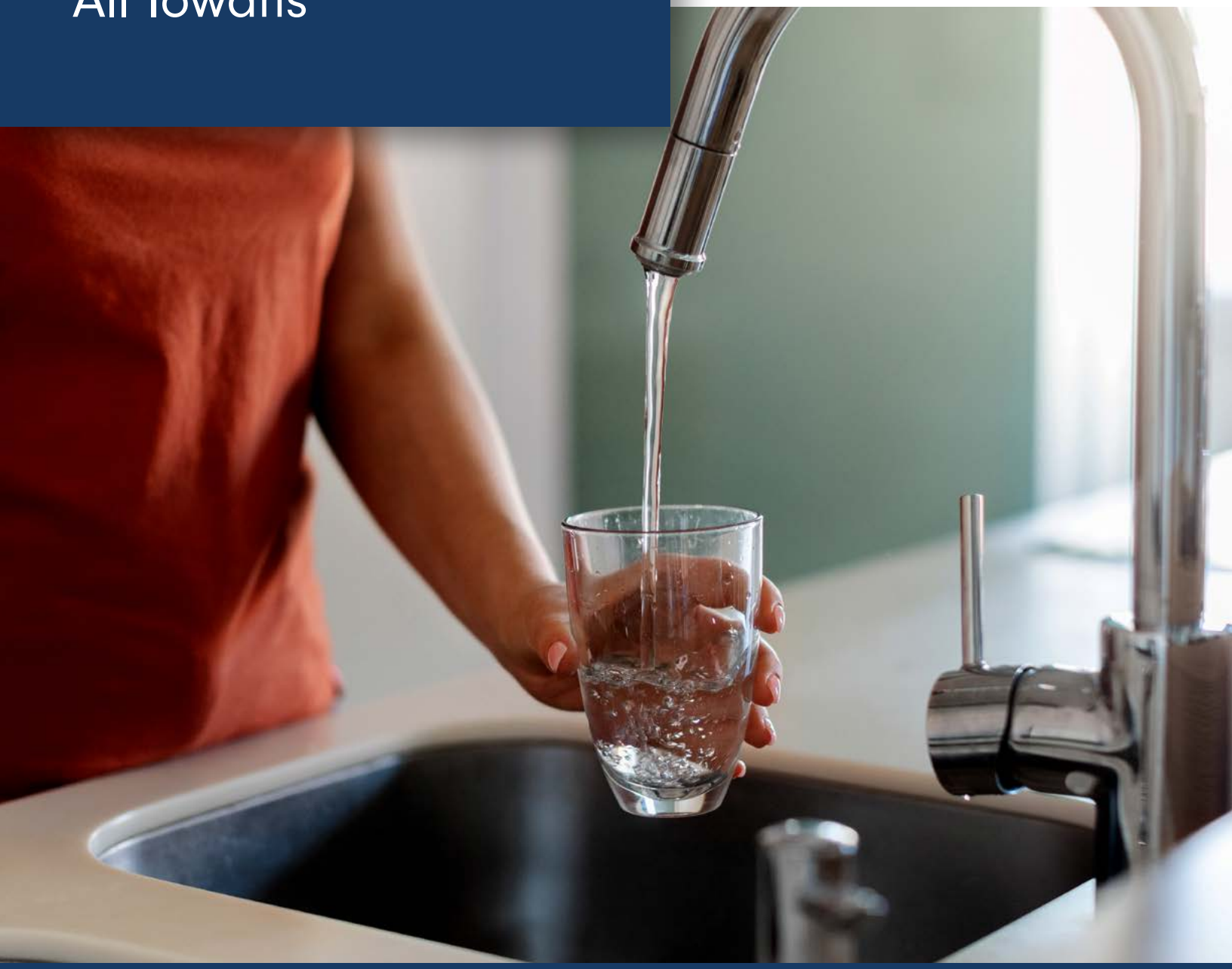
NITRATE IN DRINKING WATER

A Public Health Concern for All Iowans

Iowa Environmental Council



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Eric Bradley, Public Health Deputy Director
Linn County Public Health

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Maureen McCue, MD, Ph.D.,
Iowa Physicians for Social Responsibility

Craig Miller, Board of Directors
Iowa Environmental Council

Anne Schechinger, Midwest Director
Environmental Working Group

Mary H. Ward, Ph.D., Senior Investigator
National Cancer Institute

INTRODUCTION

Concerns over elevated nitrate levels in Iowa's water have been raised for a number of reasons in recent decades. Not only has Iowa long been known is a top contributor of nutrient pollution (nitrate and phosphorus) that fuels the Dead Zone in the Gulf of Mexico due to intensive agricultural production, but in 2023, the Iowa Cancer Registry reported that Iowa has the second-highest rate of cancer incidence among U.S. states and is the only state with a rising cancer rate.[1] The challenges of providing drinking water that meets the nitrate health standard have received increased attention as public water systems face costly upgrades to maintain safe drinking water for customers.[2]

The U.S. Department of Health, Education, and Welfare established a drinking water regulatory standard of 10 milligrams per liter (mg/L) of nitrate-nitrogen (nitrate-N) in 1962 to prevent methemoglobinemia, a serious and potentially life-threatening condition that decreases the blood's ability to carry vital oxygen through the body.[3] This syndrome is also known as blue baby syndrome because while adverse health effects may occur at any age, methemoglobinemia is particularly life-threatening to infants, where the condition can progress rapidly to coma and death. The U.S. Environmental Protection Agency (EPA) established 10 mg/L as the maximum contaminant level (MCL) for nitrate in drinking water served by public water systems under the Safe Drinking Water Act (SDWA) in 1991.[4]

The SDWA allows EPA to set drinking water standards for public water systems, which are defined as systems that have at least 15 connections or serve at least 25 people for 60 days of the year. While public water supplies are required to provide water that meets drinking water standards, private wells are not regulated for drinking water quality. A recent review by the Environmental Working Group demonstrated that private wells are seldom tested on a regular basis and thousands of wells in Iowa contain concentrations of nitrate that exceed the drinking water standard.[5]

Reported cases of methemoglobinemia 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.[6] Blue baby syndrome is rare — especially since the health-based standard for nitrate in public water supplies was adopted.

However, the health risks of nitrate in drinking water go beyond blue baby syndrome. While the drinking water standard addresses the acute toxicity health risk of methemoglobinemia, it does not protect against long-term, low-level drinking water nitrate exposure that a growing body of research has linked to chronic health issues. Research from Iowa and around the world has associated many human health concerns, including birth defects and cancers, with long-term exposure to nitrate at concentrations lower than the 10 mg/L drinking water standard.[7]

In this paper, the Iowa Environmental Council (IEC) reviews some of the most compelling research relating to these broader public health risks, with a focus on human-based, epidemiological studies. The report concludes with recommendations to protect individual and public health.

DRINKING WATER STANDARD FOR NITRATE

The current drinking water standard for nitrate, set by the U.S. Environmental Protection Agency (EPA), 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.
- 44.3 milligrams per liter (mg/L) as total nitrate, or NO_3 — the same as 44.3 parts per million (ppm) NO_3.

EPA restarted a human health assessment of nitrate in 2023.[1] The assessment could create a foundation for updating the nitrate drinking water standard.

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

1 Integrated Risk Information System. "Nitrate: Assessment Status." *EPA.gov*, U.S. Environmental Protection Agency, https://iris.epa.gov/ChemicalLanding/&substance_nmbr=76. Accessed 28 February 2024.

1 West, Michele M., et al. 2023. 2023 Cancer in Iowa. Iowa Cancer Registry, College of Public Health, University of Iowa. https://shri.public-health.uiowa.edu/wp-content/uploads/2023/02/cancer-in-iowa-2023.pdf.

2 Payne, Kate. "Des Moines Water Works Advances Plans to Build New Wells in Light of River Pollutants." *Iowa Public Radio,* 22 April 2021, https://www.iowapublicradio.org/ipr-news/2021-04-22/des-moines-water-works-advances-plans-to-build-new-wells-in-light-of-river-pollutants.

3 U.S. Department of Health, Education, and Welfare. 1962. Public Health Service Drinking Water Standards 1962, Public Health Service Publication No. 956, Washington, DC, available at https://nepis.epa.gov/Exe/ZyPDF.cgi/2000TP5L.PDF?Dockey=2000TP5L.PDF. Accessed 19 April 2024.

4 Anita M. Thompkins to EPA Regional Water Division Directors, Regions I-X, November 30, 2020, U.S. EPA, Use of Total Nitrate and Nitrite Analysis for Compliance Determinations with the Nitrate Maximum Contaminant Level - 40 CFR §141.23, WSG #213, https://www.epa.gov/sites/default/files/2021-01/documents/wsg_213_nitrate_wsg_11-30-2020_signed_508-compliantfinal.pdf. Accessed 19 April 2024.

5 Environmental Working Group. "Iowa's Private Wells Contaminated by Nitrate and Bacteria." *EWG.org,* April 2019, https://www.ewg.org/interactive-maps/2019_iowa_wells/. Accessed 28 February 2024.

6 Health Canada. 2013. Guidelines for Canadian Drinking Water Quality: Guideline Technical Document — Nitrate and Nitrite. Water and Air Quality Bureau, Healthy Environments and Consumer Safety Branch, Health Canada, Ottawa, Ontario. (Catalogue No H144-13/2-2013EPDF). https://www.canada.ca/content/dam/canada/health-canada/migration/healthy-canadians/publications/healthy-living-vie-saine/water-nitrate-nitrite-eau/alt/water-nitrate-nitrite-eau-eng.pdf.

7 Temkin, Alexis, et al. 2019. Exposure-based assessment and economic valuation of adverse birth outcomes and cancer risk due to nitrate in United States drinking water. *Environmental Research,* Vol. 176:108442. https://doi.org/10.1016/j.envres.2019.04.009.

HOW NITRATE AFFECTS HEALTH

Analyses of animal research and human epidemiological studies suggest links between elevated nitrate concentrations in drinking water and several birth defects, cancers, thyroid disease, and a variety of other health concerns.[8] A growing body of research suggests that nitrate concentrations lower than the current drinking water standard of 10 mg/L may be harmful when there is long-term, chronic exposure or when an individual's health situation makes them more susceptible to adverse effects.[9]

Nitrate is not considered to pose a serious health risk unless it is consumed. When nitrate is ingested, it is reduced within the body to nitrite by bacteria in the mouth and digestive tract. Nitrite is unsafe at levels much lower than nitrate (the drinking water standard for nitrite is 1 mg/L). Then, nitrite reacts in the body to form N-nitroso compounds (NOCs). NOCs are widely considered to be carcinogenic and teratogenic (cause birth defects) and to contribute to a variety of health problems.[10]

Links between NOCs and health problems were first identified in animal studies more than five decades ago.[11] Scientists have found that NOCs can cause mutations and cancerous tumors in mature somatic cells and organs.[12] Similar processes are also thought to affect developing cells and organ systems.

Many of the human studies have been prompted from findings from animal studies.[13] 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.[14] 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.[15]

A 2018 analysis of health studies of nitrate in drinking water found the strongest associations between drinking water nitrate exposure and colorectal cancer, thyroid disease, and neural tube birth defects.[16] This report was an update of a 2005 review and focused on evidence of nitrate's link to major structural birth defects, bladder and colorectal cancers, and emerging links to other types of cancers. It must be noted, however, that the number of studies on health outcomes and drinking water nitrate exposure is small and disease is often caused by a combination of risk factors. More studies are needed to confirm and quantify causal relationships.

8 Ward, Mary H. 2009. Too Much of a Good Thing? Nitrate from Nitrogen Fertilizers and Cancer. ***Reviews of Environmental Health***, Vol. 24(4):357-363. https://doi.org/10.1515/reveh.2009.24.4.357; Weyer, Peter. 2016. "Source Water Quality in Iowa: Drinking Water and Health." Center for Health Effects of Environmental Contamination, University of Iowa. Presentation at ***Iowa's Drinking Water: Could Flint Happen Here? Symposium/Forkenbrock Series on Public Policy,*** 17 June 2016, Des Moines, Iowa; Ward, Mary H., et al. 2018. Drinking Water Nitrate and Human Health: An Updated Review. ***International Journal of Environmental Research and Public Health***, Vol. 15(7):1557. https://doi.org/10.3390/ijerph15071557.

9 Weyer, P.J., et al. 2001. Municipal Drinking Water Nitrate Level and Cancer Risk in Older Women: The Iowa Women's Health Study. ***Epidemiology,*** Vol. 12(3):327–328. https://doi.org/10.1097/00001648-200105000-00013; Brender, Jean D., et al. 2013. Prenatal Nitrate Intake from Drinking Water and Selected Birth Defects in Offspring of Participants in the National Birth Defects Prevention Study. ***Environmental Health Perspectives***, Vol. 121(9):1083-1089. https://ehp.niehs.nih.gov/doi/10.1289/ehp.1206249.

10 International Agency for Research on Cancer (IARC). 2010. Ingested Nitrate and Nitrite, and Cyanobacterial Peptide Toxins. ***IARC Monograph Evaluation of Carcinogenic Risk to Humans***, Vol. 94:9-464. https://publications.iarc.fr/112; Zeman, Catherine, et al. 2011. New questions and insights into nitrate/nitrite and human health effects: a retrospective cohort study of private well users' immunological and wellness status. ***Journal of Environmental Health***, Vol. 74(4):8-18. https://pubmed.ncbi.nlm.nih.gov/22187853/.

11 Druckrey, H., et al. 1967. [Organotropic carcinogenic effects of 65 different N-nitroso-compounds on BD-rats]. ***Z Krebs-forsch,*** Vol. 69: 103–201. https://doi.org/10.1007/BF00524152.

12 Hebels, Dennie G.A.J., et al. 2009. Molecular Signatures of N-nitroso Compounds in Caco-2 Cells: Implications for Colon Carcinogenesis. ***Toxicological Sciences***, Vol. 108(2):290-300. https://doi.org/10.1093/toxsci/kfp035.

13 Panesar, Nirmal S., and Kam W. Chan. 2000. Decreased Steroid Hormone Synthesis from Inorganic Nitrite and Nitrate: Studies in Vitro and in Vivo. ***Toxicology and Applied Pharmacology***, Vol. 169:222-230. https://doi.org/10.1006/taap.2000.9079; Hansen, Pernille R., et al. 2009. Evaluation of Endocrine Disrupting Effects of Nitrate after in Utero Exposure in Rats and of Nitrate and Nitrite in the H295R and T-Screen Assay. ***Toxicological Sciences***, Vol. 108(2):437-444. doi:10.1093/toxsci/kfp023; Health Canada 2013.

14 Jaeger, James W., et al. 1999. Endocrine, immune, and behavioral effects of aldicarb (carbamate), atrazine (triazine) and nitrate (fertilizer) mixtures at groundwater concentrations. ***Toxicology and Industrial Health***, Vol. 15(1-2):133-150. https://doi.org/10.1177/074823379901500111.

15 Guillette, Louis J. Jr., and Thea M. Edwards. 2005. Is Nitrate an Ecologically Relevant Endocrine Disruptor in Vertebrates? ***Integrative and Comparative Biology***, Vol. 45(1):19-27. https://doi.org/10.1093/icb/45.1.19.

16 Ward et al. 2018.

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 several 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" compounds (compounds that can be converted to a NOC). Some animal studies and epidemiologic research suggests that nitrate consumption in drinking water is most problematic when combined with compounds that can react with nitrite to form NOCs, such as certain drugs and agricultural chemicals.[17]

Some vegetables, especially leafy greens, are natural sources of dietary nitrate and nitrite. However, the source of consumption appears to be important in linking exposure to adverse health outcomes. 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]

17 Jaeger et al. 1999.

18 Ward 2009.

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 in Iowa primarily comes from agricultural sources such as fertilizers used on crop fields, livestock manure, and soil tillage, but it can also come from urban and other rural sources such as fertilized lawns, leaking septic tanks, and wastewater treatment systems.[20] Iowans are particularly vulnerable to health impacts from nitrate pollution because concentrations of nitrate in Iowa's streams and groundwater have ranked among the highest in the U.S., even higher than elsewhere in the Corn Belt and Northern Great Plains.[21]

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. Local drinking water utilities provide these drinking water reports, often called consumer confidence reports, in various formats.

In 2021,18 public water systems in Iowa — including municipalities, rural water districts, churches, residential care facilities and mobile home parks — reported nitrate or nitrite levels that exceeded federal safe drinking limits, according to the Iowa Department of Natural Resources (DNR) annual drinking water compliance report.[22] 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 DNR.[23]

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, especially older private wells, for their water supply may be at a greater risk of ingesting elevated concentrations of nitrate or other 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 https://hhs.iowa.gov/public-health/data/environment/well-water/nitrate. This data is available from the state's Grants to Counties Program. The program provides free private well testing for bacteria, arsenic, and nitrate, as well as assistance with well closure or renovation.[24]

A 2019 Environmental Working Group analysis of private well data from 2002 to 2017 found that 12 percent of private wells averaged at or above the 10 mg/L drinking water standard for nitrate.[25] A 2015 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.[26]

19 Dubrovsky, Neil M., et al. 2010. The Quality of Our Nation's Waters — Nutrients in the Nation's Streams and Groundwater, 1992-2004. U.S. Geological Survey. Circular 1350. https://pubs.usgs.gov/circ/1350/pdf/circ1350.pdf.

20 Iowa Department of Agriculture and Land Stewardship, Iowa Department of Natural Resources and Iowa State University College of Agriculture and Life Sciences. 2017. Iowa Nutrient Reduction Strategy: A science and technology-based framework to assess and reduce nutrients in Iowa waters and the Gulf of Mexico. https://www.nutrientstrategy.iastate.edu/sites/default/files/documents/2017%20INRS%20Complete_Revised%202017_12_11.pdf. (Iowa NRS 2017).

21 Kalkhoff, Stephen J., et al. 2000. Water Quality in the Eastern Iowa Basins, Iowa and Minnesota, 1996-98. U.S. Geological Survey, U.S. Department of the Interior. Circular 1210. https://pubs.usgs.gov/circ/circ1210/pdf/Circular1210.pdf.

22 Iowa Department of Natural Resources. 2022. State of Iowa Public Drinking Water Program 2021 Annual Compliance Report. https://www.iowadnr.gov/Portals/idnr/uploads/water/wse/CY%202021%20Full%20Report%20DNR%20Approved.pdf. At 18.

23 Eller, Donnelle. "High Nitrate Levels Plague 60 Iowa Cities, Data Show." ***Des Moines Register***, 4 July 2015, https://www.desmoinesregister.com/story/money/agriculture/2015/07/04/high-nitrates-iowa-cities/29720695/.

24 Iowa Department of Health and Human Services. "Grants to Counties Water Well Program." ***HHS.Iowa.gov,*** State of Iowa, https://hhs.iowa.gov/public-health/environmental-health/grants-counties-water-well-program. Accessed 19 April 2024.

25 Environmental Working Group 2019.

26 Wheeler, David C., et al. 2015. Modeling groundwater nitrate concentrations in private wells in Iowa. ***Science of the Total Environment,*** Vol. 536:481-488. https://doi.org/10.1016/j.scitotenv.2015.07.080.

DRINKING WATER NITRATE AND BIRTH DEFECTS

A number of epidemiologic studies have suggested an association between nitrate exposure and reproductive problems, including several birth defects due to exposure of pregnant women to elevated nitrate in drinking water.[27] In Ward et al.'s 2018 review, the authors found positive associations between higher drinking water nitrate exposure during pregnancy and neural tube or central nervous system defects, such as spina bifida and oral cleft defects, in five of six studies since the 1980s. Temkin et al.'s 2019 analysis found that, assuming the associations are causal, nitrate exposure from drinking water could be related to 2,939 cases of very low birth weight, 1,725 cases of very preterm birth, and 41 cases of neural tube defects annually in the U.S.

- 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 greater than 5 mg per day 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.[28]

- 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 recommended by physicians to prevent neural tube defects and improve reproductive health outcomes).[29]

- 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 nearly twice as likely to have an NTD-affected pregnancy as women with lower levels of nitrate in their water.[30]

- 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.[31] Evidence of dose-response relationships such as these are critical to determining a causal relationship between exposure to nitrate in drinking water and birth defects.

27 Manassaram et al. 2006.

28 Brender et al. 2013.

29 Holtby, Caitlin E., et al. 2014. A Population-Based Case-Control Study of Drinking-Water Nitrate and Congenital Anomalies Using Geographic Information Systems (GIS) to Develop Individual-Level Exposure Estimates. ***International Journal of Environmental Research and Public Health***, Vol. 11(2):1803-1823. https://doi.org/10.3390%2Fijerph110201803.

30 Brender, Jean D., et al. 2004. Dietary Nitrites and Nitrates, Nitrosatable Drugs, and Neural Tube Defects. ***Epidemiology,*** Vol. 15(3):330-336. doi:10.1097/01.ede.0000121381.79831.7b. https://journals.lww.com/epidem/fulltext/2004/05000/dietary_nitrites_and_nitrates,_nitrosatable_drugs,.14.aspx.

31 Dorsch, Margaret M., et al. 1984. Congenital Malformations and Maternal Drinking Water Supply in Rural South Australia: A Case-Control Study. ***American Journal of Epidemiology,*** Vol. 119(4):473-486. https://doi.org/10.1093/oxfordjournals.aje.a113764.

DRINKING WATER NITRATE AND CANCER

In 2019, Temkin et al. published a comprehensive assessment of drinking water nitrate exposure for the entire population of the United States. Under the assumption that the associations between nitrate and cancer were causal, the authors used the exposure assessment to analyze the number of nitrate-attributable diseases and the associated economic costs. For bladder, colorectal, kidney, ovarian, and thyroid cancers in the U.S., they estimated 2,300 to 12,594 nitrate-attributable cancer cases annually. Colorectal cancer accounted for 54-82% of all cases. Annual economic costs associated with these cancer cases includes $250 million to $1.5 billion for medical expenditures and potentially $1.3 to $6.5 billion in lost productivity (in 2014 U.S. dollars).[32]

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 4.2% of all new cancers in the US.[33] Incidence rates of bladder cancer in the U.S. decreased slowly during the late 2000s, but accelerated to 1.7% per year from 2015 through 2019.[34] It is the fourth most commonly diagnosed cancer in men.[35] Iowa ranks 12th in the nation for bladder cancer.[36]

- A 2016 study followed the health of about 35,000 postmenopausal women who participated in the Iowa Women's Health Study from 1986-2010. This analysis extended an earlier evaluation of municipal drinking water nitrate and cancer risk in the cohort (Weyer et al. 2001). The researchers found a higher prevalence of bladder cancer among those exposed to water with greater than 5 mg/L of drinking water nitrate 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 intake. Smoking, in combination with nitrate, was found to increase the risk of bladder cancer. Several other possible influences, including exposure to trihalomethanes, a water treatment 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.[37]

- The 2001 Iowa Women's Health Study evaluation conducted by Weyer et al. was based on 57 bladder cancer cases. Women whose average drinking water nitrate exposure level was greater than 2.46 mg/L — an average level that is 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).[38]

- A 2015 case-control study of bladder cancer in Spain that included cases diagnosed from 1998-2001 reported an increased risk of bladder cancer among subjects with the longest exposure (greater than 20 years) to 2.15 mg/L or more of nitrate-N in drinking water. Elevated risk was linked to a long duration of exposure at nitrate levels well below the drinking water standard.[39]

- 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.[40]

- 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 nearly two times more likely to die from bladder cancer than those who had the lowest exposure.[41]

32 Temkin et al. 2019.

33 Surveillance, Epidemiology, and End Results Program. "Cancer Stat Facts: Bladder Cancer." ***SEER.cancer.gov,*** National Cancer Institute, https://seer.cancer.gov/statfacts/html/urinb.html. Accessed 28 February 2024.

34 American Cancer Society. 2022. About Bladder Cancer: Key Statistics for Bladder Cancer. https://www.cancer.org/content/dam/CRC/PDF/Public/8557.00.pdf. At 6.

35 U.S. Cancer Statistics. 2020. "United States Cancer Statistics: Data Visualizations – Top 10 Cancers by Rates of New Cancer Cases: United States, 2020, All Races and Ethnicities, Male." ***CDC.gov***, Centers for Disease Control and Prevention, https://gis.cdc.gov/Cancer/USCS/#/AtAGlance/. Accessed 28 February 2024.

36 West et al. 2023.

37 Jones, Rena R., et al. 2016. Nitrate from Drinking Water and Diet and Bladder Cancer Among Postmenopausal Women in Iowa. ***Environmental Health Perspectives***, Vol. 124(11):1751-1758. https://ehp.niehs.nih.gov/doi/10.1289/EHP191.

38 Weyer et al. 2001.

39 Espejo-Herrera, Nadia, et al. 2015. Nitrate in drinking water and bladder cancer risk in Spain. ***Environmental Research***, Vol. 137:299-307. https://doi.org/10.1016/j.envres.2014.10.034.

40 Volkmer, Bjoern G., et al. 2005. Influence of nitrate levels in drinking water on urological malignancies: a community-based cohort study. ***BJU International***, Vol. 95(7):972-976. https://doi.org/10.1111/j.1464-410X.2005.05450.x.

41 Chiu, Hui-Fen, et al. 2007. Nitrate in Drinking Water and Risk of Death from Bladder Cancer: An Ecological Case-Control Study in Taiwan. ***Journal of Toxicology and Environmental Health, Part A: Current Issues***, Vol. 70(12):1000-1004. https://doi.org/10.1080/15287390601171801.

COLORECTAL CANCER

Studies have increasingly shown an association between nitrate in drinking water and colorectal cancer risk. Some studies found that associations between colorectal cancer and nitrate intake were primarily associated with other risk factors or among susceptible subgroups, such as those with low vitamin C intake or high meat intake, or may be limited to proximal colon cancer.[42]

- Temkin et al.'s 2019 meta-analysis of eight studies found a statistically significant association between nitrate exposure and colorectal cancer risk. The data suggest that nitrate exposure could account for 1,233 to 10,379 colorectal cancer cases per year, which is equivalent to 1-8 percent of the total cases. Of those cases, 12-24 percent are private well users, especially those with well water at 5 mg/L or more.[43]

- One study included in the 2019 Temkin et al. meta-analysis, a 2018 study from Denmark, found a positive association between drinking water nitrate and colorectal cancer at levels well below the 10 mg/L drinking water standard.[44] After analyzing over 30 years of data from more than 2.7 million Danes, researchers found those exposed to drinking water nitrate above 0.87 mg/L had a statistically significant increased risk of colorectal cancer.

- A 2016 case-control study in Spain and Italy, also included in Temkin et al. 2019, reported a positive association between colorectal cancer risk and waterborne nitrate ingestion, mainly among subgroups with other risk factors.[45] Associations were higher among men and subjects with high red meat intake.

However, studies of the Iowa women cohort found no association between drinking water nitrate and colorectal cancer, even when considering red meat and vitamin C intake.[46]

42 De Roos, Anneclaire J., et al. 2003. Nitrate in Public Water Supplies and the Risk of Colon and Rectum Cancers. ***Epidemiology,*** Vol. 14(6):640-649. https://doi.org/10.1097/01.ede.0000091605.01334.d3; McElroy, Jane A., et al. 2008. Nitrogen-nitrate exposure from drinking water and colorectal cancer risk for rural women in Wisconsin, USA. ***Journal of Water & Health,*** Vol. 6(3):399-409. https://doi.org/10.2166/wh.2008.048; Espejo-Herrera, Nadia, et al. 2016. Colorectal cancer risk and nitrate exposure through drinking water and diet. ***International Journal of Cancer,*** Vol. 139(2):34-46. https://doi.org/10.1002/ijc.30083.

43 Temkin et al. 2019.

44 Schullehner, Jorg, et al. 2018. Nitrate in drinking water and colorectal cancer risk: A nationwide population based cohort study. ***International Journal of Cancer,*** Vol. 143(1):73-79. https://doi.org/10.1002/ijc.31306.

45 Espejo-Herrera et al. 2016.

46 Jones, Rena R., et al. 2019. Ingested nitrate, disinfection by-products, and risk of colon and rectal cancers in the Iowa Women's Health Study cohort. ***Environment International,*** Vol. 126: 242-251. https://doi.org/10.1016/j.envint.2019.02.010.

OTHER CANCER RISK EVIDENCE

Recent research shows links between nitrate consumption and other forms of cancer. Studies demonstrating increased risk of childhood, kidney, ovarian, and thyroid cancer are described below.

CHILDHOOD CANCER: A 2021 study of Danish children found that drinking water nitrate may increase the risk of childhood central nervous system cancers (CNC) in children 15 years or younger.[47] The Denmark case-control study looked at children with leukemia, lymphoma, and CNC and analyzed drinking water nitrate exposure during preconception, prenatal, and postnatal periods. While no evidence of association with leukemia or lymphoma was found, associations between CNC and nitrate exposure greater than 5.65 mg/L was observed for all periods.

KIDNEY CANCER: A 2017 report on the Iowa Women's Health Study found that nitrate levels greater than 5 mg/L in public water supplies were associated with an increased risk of kidney cancer.[48] While that study did not find differences in risk based on vitamin C intake or smoking habits, an earlier study found increased kidney cancer risk for Iowans with high drinking water nitrate exposure and above median red meat intake or below median vitamin C intake.[49]

OVARIAN CANCER: An Iowa Women's Health Study evaluation of ovarian cancer in postmenopausal women found that ovarian cancer risk was more than twice as high among women with the highest drinking water nitrate exposure compared to women with the lowest drinking water nitrate exposure.[50] The association was stronger among women with vitamin C intake below the median level.

THYROID CANCER: 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. Women who drank water with nitrate levels exceeding 5 mg/L for five years or more were 2.6 times more at risk of thyroid cancer than women whose water nitrate levels never exceeded 5 mg/L. Greater dietary intake of nitrate was also associated with increased risk of thyroid cancer in this study.[51]

Other studies not included in this review suggest nitrate consumption might also be associated with prostate cancer,[52] as well as other reproductive issues,[53] macular degeneration,[54] digestive problems, and bone, muscle, and nerve complaints.[55]

47 Stayner, Leslie T., et al. 2021. Exposure to nitrate from drinking water and the risk of childhood cancer in Denmark. *Environment International*, Vol. 155:106613. https://doi.org/10.1016/j.envint.2021.106613.

48 Jones, Rena R., et al. 2017. Ingested Nitrate, Disinfection By-products, and Kidney Cancer Risk in Older Women. *Epidemiology*, Vol. 28(5):703-711. *doi:*10.1097/EDE.0000000000000647. https://journals.lww.com/epidem/Fulltext/2017/09000/Ingested_Nitrate,_Disinfection_By_products,_and.10.aspx.

49 Ward, Mary H., et al. 2007. Nitrate in public water supplies and the risk of renal cell carcinoma. *Cancer Causes and Control,* Vol. 18:1141–1151. https://doi.org/10.1007/s10552-007-9053-1.

50 Inoue-Choi, Maki, et al. 2014. Nitrate and nitrite ingestion and risk of ovarian cancer among postmenopausal women in Iowa. *International Journal of Cancer*, Vol. 137(1):173-82. https://doi.org/10.1002/ijc.29365.

51 Ward, Mary H., et al. 2010. Nitrate Intake and the Risk of Thyroid Cancer and Thyroid Disease. *Epidemiology*, 21(3): 389-95. *doi:*10.1097/EDE.0b013e3181d6201d. http://journals.lww.com/epidem/Abstract/2010/05000/Nitrate_Intake__and_the_Risk_of_Thyroid_Cancer_and.18.aspx.

52 Donat-Vargas, Carolina, et al. 2023. Long-Term Exposure to Nitrate and Trihalomethanes in Drinking Water and Prostate Cancer: A Multicase–Control Study in Spain (MCC-Spain). *Environmental Health Perspectives,* 131(3):37004. https://doi.org/10.1289/ehp11391.

53 Manassaram, Deana M., et al. 2006. A Review of Nitrates in Drinking Water: Maternal Exposure and Adverse Reproductive and Developmental Outcomes. *Environmental Health Perspectives*, Vol. 114(3):320-327. https://doi.org/10.1289/ehp.8407.

54 Klein, Barbara E.K., et al. 2013. Nitrate-nitrogen levels in rural drinking water: Is there an association with age-related macular degeneration? *Journal of Environmental Science and Health, Part A: Toxic/Hazardous Substances and Environmental Engineering*, Vol. 48(14): 1757–1763. https://doi.org/10.1080/10934529.2013.823323.

55 Zeman, Catherine, et al. 2011. New Questions and Insights into Nitrate/Nitrite and Human Health Effects: A Retrospective Cohort Study of Private Well Users' Immunological and Wellness Status. *Journal of Environmental Health*, Vol. 74(4):8-18. https://pubmed.ncbi.nlm.nih.gov/22187853/.

TAKING ACTION

High-quality, peer-reviewed epidemiologic research cited in this paper demonstrates the health effects of nitrate pollution that go far beyond blue baby syndrome. Findings in these studies present evidence that the real human and economic costs may include multiple serious adverse health impacts and disease, leading to avoidable deaths, increased health care costs, and lost economic productivity. These costs must be weighed seriously as we develop, debate, and implement policy solutions and consider the benefits of allocating additional public and private resources to prevent and treat nitrate pollution.

While more research is needed to better understand risks associated with nitrate exposure from drinking water, recent studies provide compelling evidence to act now to reduce pollution and improve water quality in Iowa. Based on a growing body of research showing long-term exposure at nitrate levels far below the drinking water standard of 10 mg/L, U.S. EPA should strengthen the drinking water standard for nitrate to 5 or even 3 mg/L to protect public health, prevent disease, and save lives.

Solving Iowa's nitrate problems will require political will to take regulatory action. Iowa's Nutrient Reduction Strategy (NRS) offers science-based recommendations to prevent and mitigate nitrate and phosphorus pollution, but does not provide an actual strategy to implement the identified measures.[56] It relies on voluntary action to reduce nutrient pollution from agricultural sources. Achieving the pollution reduction goals set forth in the NRS will not only require a robust implementation plan with clear timelines, it will require a transformation in agriculture that includes universal adoption of basic conservation practices, a statewide watershed approach, and enforceable accountability measures.[57]

Iowans should 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.[58] Those who get their drinking water from a private well should have their water tested regularly. Free testing with consultation is available through most county health departments. Where water has elevated nitrate levels, another drinking water source may be advisable while seeking to resolve the problem.

Individual Iowans *can* make a difference as advocates for Iowa's water. All Iowans should contact their elected officials to express their concerns about Iowa's drinking water resources. Ask lawmakers to:

Take urgent action to address all sources of nitrate pollution at 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 initiatives to increase private well testing and grants or cost-share funds for treatment of contaminated private wells.

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.

56 Iowa NRS 2017.

57 Iowa Environmental Council. 2016. Healthy Lands, Healthy Waters: A Watershed Framework for Iowa. http://www.iaenvironment.org/webres/File/Program%20Publications/Healthy_Lands_Healthy_Waters_Jan2016.pdf.

58 U.S. Environmental Protection Agency. "Consumer Confidence Reports: Annual Drinking Water Quality Reports for Iowa." *EPA.gov,* https://ordspub.epa.gov/ords/safewater/f?p=136:103:::NO:RP,103:P103_STATE:IA.

HOME TREATMENT TO REMOVE NITRATE FROM DRINKING WATER

While boiling water is often recommended to eliminate some types of contaminants, it is critical to note that boiling will not remove nitrate and can actually increase nitrate concentrations. Bottled water is not necessarily lower in nitrate or other pollutants.

Several home water treatment options can reduce high nitrate in drinking water. Less expensive water filters generally do not remove nitrate, including Brita pitchers and filtered water from the refrigerator.

Other treatments such as reverse osmosis, ion exchange, or distillation can be effective. These processes can be expensive and are not always practical to install, but they might be an appropriate option, especially for those who are pregnant, planning to start a family, or have a vulnerable immune system. Note: The use of reverse osmosis systems may remove fluoride, which at optimal levels is an effective measure for preventing tooth decay.

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/WellWaterQualityandHomeTreatmentSystems.pdf.

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Iowa Environmental Council

505 Fifth Ave, Ste. 850 • Des Moines, IA 50309

Phone: 515-244-1194

Web: iaenvironment.org

Email: iecmail@iaenvironment.org

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