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A Survey and Analysis of Educational Materials Addressing the Health Consequences of Drinking Nitrate Contaminated Water in Medical Clinics Located in the Most At-Risk Areas of Nebraska: Are Healthcare Providers Equipped to Protect and Educate Their Patients?

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A Survey and Analysis of Educational Materials Addressing the Health Consequences of Drinking Nitrate Contaminated Water in Medical Clinics Located in the Most At-Risk Areas of Nebraska: Are Healthcare Providers Equipped to Protect and Educate Their Patients?

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Abstract

Background: Eighty five percent of Nebraskans rely heavily on groundwater sources, including private wells, as their primary source of drinking water. Nitrate is one of the most common chemicals found in private well water. Numerous studies demonstrated the serious human health consequences from prolonged nitrate exposure. Therefore, due to the potential health risks, this project aimed to identify and evaluate the existing knowledge and awareness among healthcare providers as well as the educational materials in medical clinics in Nebraska related to health effects of drinking nitrate contaminated water.

Methods: An 8 multiple choice question survey was developed using Microsoft Forms. The survey was disseminated to healthcare providers in medical clinics located in several counties of Nebraska with high nitrate contaminated waters. Respondents completed the survey electronically through a unique weblink as well as in-person meetings. All responses were stored in the Microsoft Forms database. Later, analytical functions were used to perform quantitative analysis.

Results and Findings: Four key findings resulted from the survey and its analysis.

1. The majority of health care providers (63%) have had no to very little formal education or training on the adverse health consequences of drinking nitrate contaminated water.
2. Currently, many providers (63%) do not have access to any educational materials regarding adverse health consequences of drinking nitrate contaminated water.
3. The top educational materials health care providers requested to educate themselves were educational videos and continuing education credits.

4. The top educational materials health care providers requested to educate their patients were brochures, flyers, and posters.

Conclusion: Many health care providers have no-to-little formal training or education on the adverse health consequences of drinking nitrate contaminated water. Additionally, providers reported not having access to educational materials regarding the health consequences of drinking nitrate contaminated water. Based on our assessment, educational materials for clinics are needed in the locations surveyed. To increase education and awareness, we suggest offering health care providers educational videos and continuing education credits on hazards and dangers of nitrate in drinking water. To help providers better educate their patients, we suggest the development of brochures, flyers and posters on health concerns of nitrate in drinking water. Because of limitations in the sample size, we recommended expanding the survey to include more questions and surveying medical clinics across the entire state to draw more representative conclusions. By evaluating the needs of health care workers on water quality related health issues, we can help with future education and outreach efforts to reduce health impacts associated with consuming nitrate contaminated water.

Acknowledgements

This project was inspired by my work for the Water Climate and Health Program at the University of Nebraska Medical Center. Dr. Jesse Bell and Meghan Langel introduced me to the complexities and intersectionality of the environment and human health. Not only are Dr. Bell and Meghan wonderful academics, but their passion to work towards a healthier state/nation/world has been very inspiring to me. It has been my pleasure to have the opportunity to work closely with them. I could not have conducted this project without their continued support, mentorship, and teaching. I am greatly indebted to them both.

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Lastly, I would like to thank my family: Mom, Dad, Nick, Lily, and Carolyn. The unwavering support will always mean the most to me.

Many thanks to all,
Laura

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Chapter 1: Introduction

Project Significance:

Modern industrial agricultural practices adopt the application of numerous chemicals, eventually leading to agricultural chemicals leaching into groundwater. Unfortunately, exposure to agricultural chemicals, such as nitrate, have been linked to higher rates of certain human cancers, birth defects, spontaneous abortions, and other ailments (Ward et al., 2010). Nitrogen is an essential agricultural fertilizer, as it provides protein and other nutrients that accelerate plant growth and increases agricultural yield and production. The primary method for delivering nitrogen to plants is through the soil. To increase their productivity and revenues, agricultural producers have been using nitrogen-containing fertilizers for decades. The graph below depicts the increasing use of nitrogen fertilizers in the United States from 1960 to 2015 (Figure 1).

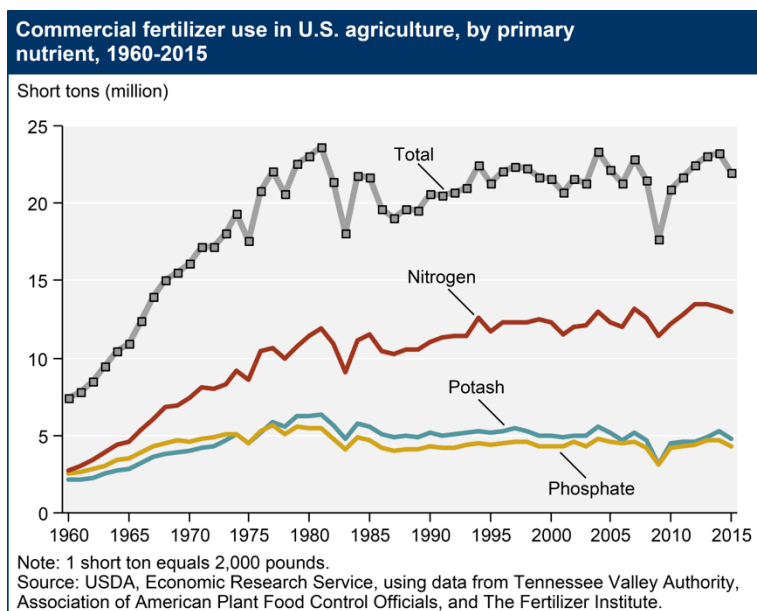


Figure 1. Commercial fertilizer use in the U.S. (United States Department of Agriculture, 2019).

Although most crops irrigated with nitrogen fertilizers are crops fed to cattle, it is not known if there is a human health effect from consuming animal meat fed with such crops. However, the most strongly linked human health consequence from consuming nitrate contaminated water is methemoglobinemia, which prohibits the circulation of oxygen throughout the body, most often affecting infants. Due to the association between methemoglobinemia and nitrate consumption, the Environmental Protection Agency (EPA) set the maximum contaminate level for nitrate in drinking water at 10mg/L in 1974, as part of the Safe Drinking Water Act (Safe Drinking Water Act, 1974).

Agricultural Practices in Nebraska

Nebraska is an agricultural state, with about 44.1 million acres (92%) of the state's total land area being used for farming and ranching (Nebraska Department of Agriculture [NDA], 2022). Nebraska is a national leading crop producer of corn, soybeans, wheat, dry edible beans, pork, grain sorghum, and eggs (NDA, 2022). The following maps developed by the Nebraska Department of Agriculture display, by county, the locations of crop farming (Figure 2).

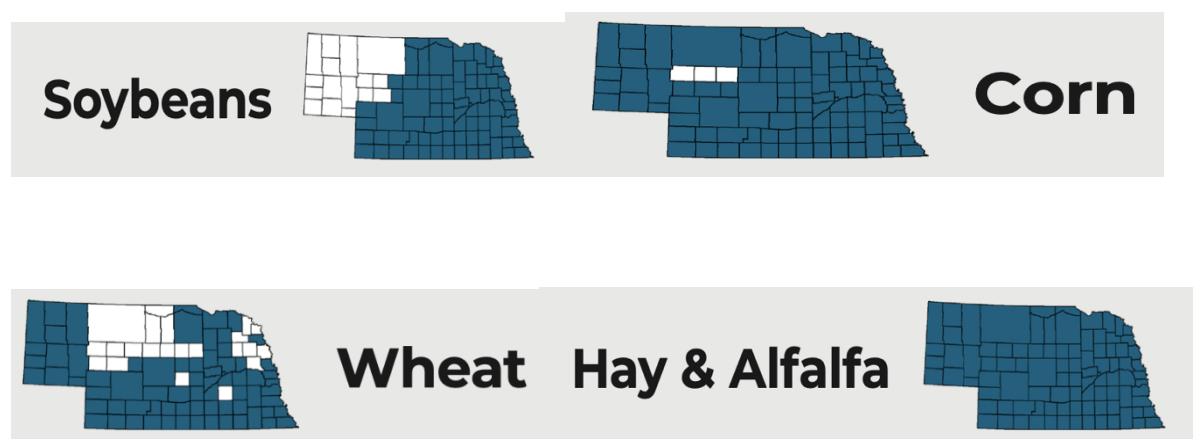


Figure 2. Crop production by county (Nebraska Department of Agriculture, 2022).

Agriculture represents a substantial contributor to Nebraska's economy. In fact, one in four people work in agriculture related jobs, and all of the state's agriculture exports translate to

\$7.4 billion in Nebraska economic activity (NDA, 2022). To maintain/achieve the highest crop production, farmers irrigate at higher rates using more fertilizers, many containing high rates of nitrogen. With the technological invention of center pivots, over 8.4 million acres of land in Nebraska are now irrigated with groundwater (Juntakut et al., 2019). National assessments have shown that the most heavily irrigated fields are producing the highest rates of nitrate groundwater contamination (Spalding & Exner, 1993). Because of nitrogen's anatomical qualities, it is highly soluble and can be easily transported into groundwater. In Nebraska, corn is grown on around 70% of irrigated crop rows, and 80% of irrigated corn is in central and eastern Nebraska (Exner-Spaulding, Hirsh, Spalding, 2014). Consequently, Nebraska is struggling with the immensity of nitrate groundwater contamination which is of special concern in central and eastern Nebraska. The map below depicts the increase of ground water contamination nationwide (Figure 3). As illustrated, Nebraska's groundwater is at high risk of nitrate contamination.

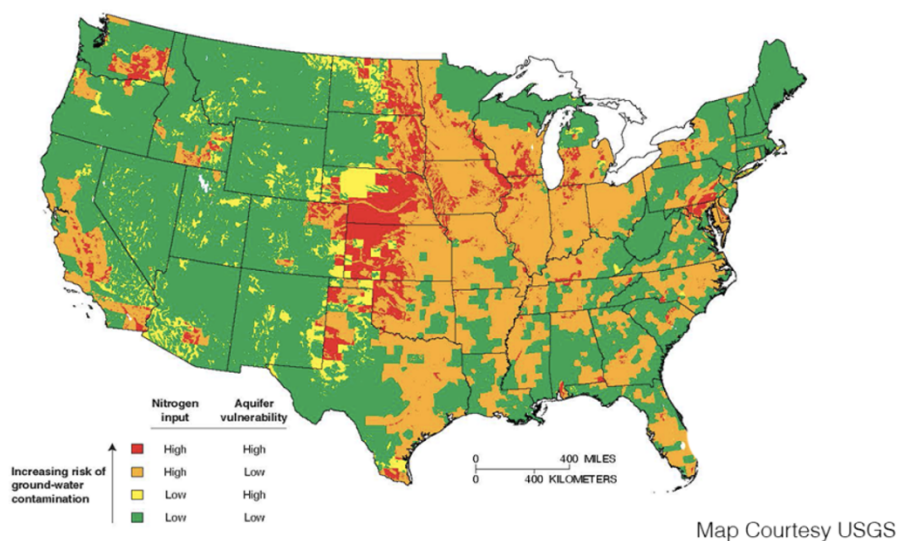


Figure 3. State vulnerability of nitrogen contamination in U.S. (United States Geological Survey, 2015).

Groundwater is an abundant and highly valuable resource in Nebraska. According to the Nebraska Department of Environment and Energy (NDEE), groundwater could cover the state with 40 feet of water if it were all pumped to the surface (NDEE, 2022). Over 85% of Nebraska's population uses groundwater for their drinking water (NDEE, 2022). Aquifers are a major water source for cities, farming and industrial uses, and the use of groundwater to irrigate crops is becoming more common than ever before (Juntakut, et. Al, 2019).

With the increasing use of fertilizers and especially those including nitrogen over the past decades, the amount of nitrogen seeping into the groundwater has also increased. Since many Nebraska farms use agricultural chemicals, the current concentrations of some of these agricultural chemicals (i.e., nitrate) in groundwater are reported at levels far above the Safe Drinking Water Act standards (Safe Drinking Water Act, 1974). Because private wells in Nebraska are typically located in agriculturally intense areas of the state and are not required to screen for chemical contaminants, many people in rural Nebraska are unaware of possible water quality and chemical contamination issues in their drinking water.

Current Regulatory Framework

Nebraska has no state-wide regulations regarding nitrogen fertilizer and irrigation practices. The state is unique in that it is divided into 23 Natural Resource Districts (NRD) which can be seen in the map below (Figure 4).

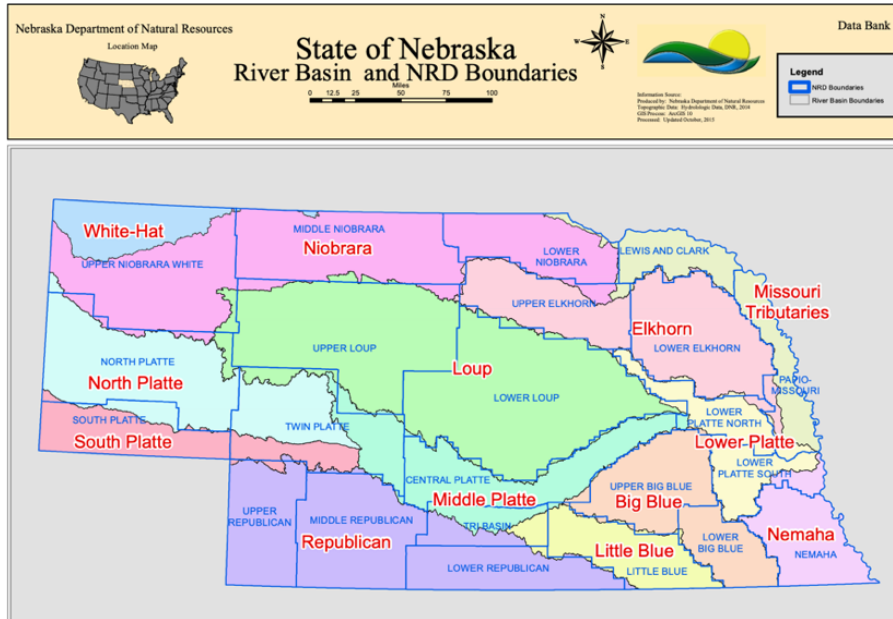


Figure 4. Natural Resource District in Nebraska (Nebraska Department of Natural Resources, 2015).

Each NRD has full control of many agricultural regulations, including water quality and fertilizer application regulations. The NRD's are comprised of local board members. Therefore, local NRD members decide the regulations for their respective districts. NRD's have made many efforts to manage and monitor nitrate groundwater contamination, but it remains a large unsolved/unregulated issue in Nebraska.

NRD's have the autonomy to set local agricultural practice regulations in their districts, but there are some national water quality acts that the United States Environmental Agency (EPA) enacted regarding water quality standards. This first act was originally named the Federal Water Pollution Control Act in 1948 but was later reorganized and changed to the "Clean Water Act" (Clean Water Act, 1977). The Clean Water Act regulates pollutants that can be dumped in the nation's waters.

In 1974, the EPA created the Safe Drinking Water Act, which regulates what contamination levels are permissible in drinking water throughout the nation. This law enforces limited levels of contaminants in public drinking water sources, in which municipalities must comply. The current contaminate level for nitrate must be 10 mg/L or below (Safe Drinking Water Act, 1974).

Because Nebraska has a rural population, many people do not have access to public water systems. Twenty percent, or 390,000, of Nebraskans drink from private domestic wells (Nebraska Department Health and Human Services, 2017). Therefore, one out of five Nebraskans access drinking water that does not fall under the Safe Drinking Water Act, as private domestic wells do not require any testing or treatment like public water sources do.

Project Aim:

With no mandate for private wells to abide by Safe Drinking Water Act regulations, like city water sources are, many rural Nebraska residents continue to consume nitrate-contaminated water from their private wells. Because of limited policy, improved public awareness towards nitrate contamination of private wells is critical to protect hundreds of thousands of rural people from the risks associated with nitrate water well consumption.

This project aimed to understand the availability and deficiencies of educational materials addressing the health consequences of nitrate contaminated drinking water by surveying health care providers in medical clinics in counties with highest levels of nitrate in their underground water throughout Nebraska.

In addition, the project aimed to explore the needs of medical providers in educating their patient population on hazards associated consuming nitrate contaminated drinking water. The information collected from this study can guide the creation and distribution of educational

materials to medical clinics across the state and eventually increasing the awareness of high-risk populations ultimately reducing the amount of people drinking nitrate-contaminated water and promoting public health through education and awareness.

Research Question:

What current educational materials regarding the health consequences of drinking nitrate contaminated water are accessible to health care providers and what educational materials would they like to have to better educate themselves and their patients?

Chapter 2: Literature Review

Health Consequences of Consumption of Nitrate Contaminated Water

Drinking nitrate contaminated water can have serious health consequences. Through the review of research and recent literature, this section describes the scientific research of potential health consequences.

The first identified scientific linkage between nitrate and adverse human health dates back to 1945. In a notorious article authored by Hunter Comly, an Iowa City physician, he described that nitrate was likely linked to methemoglobinemia (Comly, 1945). In two case studies of infant methemoglobinemia, Comly found that infants' formulas were mixed with water that was extremely high in nitrate, around 130 mg/L (Comly, 1945). From this point forward, research continued to find the threshold of acceptable nitrate levels in drinking water. Eventually, researchers settled on 10 mg/L, which is now the level of regulation in the Safe Drinking Water Act.

Though more comprehensive research of health effects of nitrate consumption needs to be conducted, it is important to still spread awareness of potential health effects from consuming nitrate contaminated water. The strongest linked health problems of nitrate consumption are methemoglobinemia, colorectal cancers, thyroid disease and neural tube defects (Ward et al., 2018)

Methemoglobinemia

Methemoglobinemia, also known as “blue baby syndrome” is an extremely serious health condition. It is potentially fatal and occurs when the hemoglobin of an infant's red blood cells is oxidized to methemoglobin that cannot release oxygen to body tissues leading to blueish

discoloration (Knobeloch et al., 2000). Though the Safe Drinking Water Act (10 mg nitrate/L) was set to prevent methemoglobinemia, recent research continues to suggest there is a range of additional health consequences from consuming nitrate contaminated water at nitrate levels lower than 10 mg/L (Ward et al., 2018).

Colorectal Cancers

There is very strong evidence that colorectal cancers are associated with nitrate consumption. Four out of the five studies that have been published regarding colorectal cancer and nitrate consumption, from 2004-2018, displayed evidence that there is an increased risk for colorectal cancer when consuming nitrate below the regulated level of 10mg/L (Schullehner et al., 2018; McElroy et al., 2008; Espejo-Herrera et al., 2016; De Roos et al., 2003).

Thyroid Disease

Many animal studies have shown that high intake of nitrate can cause enlargement of the thyroid gland, also known as hyperthyroidism (De Groef et al., 2006). Four out of the five human studies that have been conducted, showed evidence that there is potentially an association between nitrate consumption and hyperthyroidism (Van Maanen et al., 1996; Radikova et al., 2008; Tajtakova et al., 2006; Aschebrook-Kilfoy et.al, 2012). It is important to note that this association was *only* found in children, pregnant women, and women.

Neural Tubal Defects

To date, six studies have been published to better understand the relationship between nitrate intake and neural tubal defects. Five out of the six published studies show a clear association between consuming nitrate and neural tubal defects (Brender et al., 2013; Brender et al., 2004; Dorsch et al., 1984; Croen et al., 2001; Arbuckle et al., 1988; Ericson et al., 1988).

Because neural tubal effects are a form of birth defects, consuming nitrate contaminated water is a risk factor for birth defects.

Reproductive Effects

Previous researchers have suggested high nitrate intake is associated with adverse reproductive outcomes such as spontaneous abortions, fetal death, low birthweight, and congenital malformations (Ward, et. Al, 2018). Multiple studies have given evidence that there is a positive relationship between high nitrate consumption and these adverse reproductive outcomes. However, there are also studies that have displayed no relationship between the two (Ward, et.al, 2018).

Other Cancers

Other cancers, such as bladder, kidney, pediatric brain and non-Hodgkin lymphoma have very little published research to show evidence of associations. One out of the four bladder cancer studies have shown a positive association; two studies have shown an increased risk for kidney cancer; two pediatric brain cancer studies show an association between pediatric brain cancer and high nitrate intake; one out of three studies display an increased risk of Non-Hodgkin lymphoma with high nitrate intake (Ward, et.al, 2018).

Other Potential Health Effects

There is very little research on other health effects besides the ones previously mentioned. Other research that has been conducted has mixed results. Additional health consequences studied include type 1 childhood diabetes, high blood pressure and acute respiratory tract infections in children (Ward et al., 2005).

Potential Legislation

The Clean Water Act, formerly known as the Federal Water Pollution Control Act, limits pollutants that are allowed to be put in the nation's waters (Clean Water Act, 1977). The only other act currently in place is called the Safe Drinking Water Act, this act requires routine testing and treatment of public water systems (Safe Drinking Water Act, 1974). It is important to emphasize that this testing only is required of public water systems. Nebraska does not require testing for private water wells. The only reason private well water could be required to test in Nebraska is if the entity needs a state license to function, such as a daycare (Nebraska Department of Health and Human Services, 2013).

Currently, the following two bills have been introduced in the Nebraska Legislature in 2022. If passed, they both would have a tremendous impact on Nebraska's water quality and nitrate levels in drinking water. It is important to note that healthy soil can impact water contamination. If the soil is healthy, meaning it has sufficient microorganisms, enough vital nutrients to grow plants, etc., it can bind to the nitrate to help prevent the nitrate from actually reaching the groundwater (Witheetrirong et al., 2011).

Legislative Bill 925- Resilient Soils and Water Quality Act

The following are the six purposes of the act:

- (1) "Initiate first steps to accelerate the use and scope of best practices for healthy soil management
- (2) Protect and improve soil and water quality throughout the state
- (3) Protect the public's health and enhance agricultural production and profitability

- (4) Address soil health economics, resource stewardship, and managerial and environmental issues
- (5) Increase awareness, education, and promotion of healthy soil best practices through producer-to-producer, peer-to-peer, and mentoring relationships, networking, and sharing of technical information
- (6) Provide observational proof of healthy soil benefits through access to demonstration and research farms and data” (Resilient Soils and Water Quality Act, 2022).

Legislative Bill 1160- to appropriate federal funds to the Department of Environment and Energy; and to declare an emergency.

The federal Coronavirus State Fiscal Recovery Fund, as part of the American Rescue Plan of 2021, allocated \$10 million to the Department of Environment and Energy to use in the case of an emergency. The purpose of this bill is to declare a state of emergency, and use the funds to provide grants for small and rural communities to install reverse osmosis systems in community water systems where drinking water test levels are above ten parts per million of nitrate and, if appropriate, provide grant funds for use to install reverse osmosis systems if test levels for nitrate in drinking water pumped from private wells are above ten parts per million (Nebraska Legislative Bill 1160, 2022).

Role of Education and Awareness Efforts in Promoting and Enhancing Population Health

Health promotion is a foundational pillar of improving the public’s health. Health promotion can be defined as, “the process of enabling people to increase control over, and to

improve their health” (Health Promotion Glossary, 1998). Health can be promoted in a multitude of ways such as policy creation, program implementation, education, and awareness.

Because there is currently limited policy regarding private well regulations, promoting public health through education and awareness are key components to be able to enhance population health. Environmental health research must intersect with health education and promotion within populations to have the most effective impact. Education and awareness are foundational pillars to public health interventions and often used to address health issues populations face.

Currently, the President’s Task Force has a federal action plan to reduce childhood lead exposures and the associated health impacts in the United States (President’s Task Force on Environmental Health Risks and Safety Risks to Children, 2020). One of the three main goals is to “Disseminate information on lead exposure and its effects to diverse audiences, including policy makers, healthcare providers, the general public and other stakeholders” (President’s Task Force on Environmental Health Risks and Safety Risks to Children, 2020).) The federal action plan website contains numerous resources, including materials such as research articles, flyers, and posters (President’s Task Force on Environmental Health Risks and Safety Risks to Children, 2020).

Similarly, the aim of this research project was to understand health care provider’s needs to better equip them with educational materials to help disseminate information on the adverse health consequences of drinking nitrate contaminated water to protect population health. Eventually, this work will ideally reduce the health consequences these at-risk populations may be facing due to drinking nitrate-contaminated water. Education and awareness allow populations to change behaviors through empowerment of knowledge. Once a population is

made aware of an issue and understands how it is potentially impacting them, they can make more informed decisions for themselves and their families.

Program implementation is a very important aspect of improving education and awareness. Similar to the federal action plan to reduce childhood lead exposures and the associated health impacts in the United States, Nebraska has various programs and research working to reduce the associated health impacts of drinking contaminated water.

The University of Nebraska

The University of Nebraska has a number of educational programs and initiatives that work to help promote groundwater contamination awareness and well water testing. Below are ongoing efforts of the University of Nebraska.

Water, Climate, and Health Program

The Water, Climate, and Health Program is located at the University of Nebraska Medical Center. It works to tackle water quality and climate change issues impacting Nebraska. The program does so through four different avenues: research, policy development, education and training (University of Nebraska Medical Center College of Public Health, 2022). Protecting human health from negative environmental impacts is a priority for the program.

Know Your Well

Know Your Well was funded by the Nebraska Environmental Trust from 2017-2020 that educated high school students about well water testing. The program reached 19 high schools all across the state of Nebraska which provided hands-on training on how to test your wells and what levels of nutrients are acceptable. The project is still being developed in and is working to acquire more funding to expand and reach even more high schools and students, (University of Nebraska Water Center, 2022).

Water Quality + Citizen Science

This program is headed by the Department of Civil and Environmental Engineering at the University of Nebraska- Lincoln. It relies on volunteers to test ground water sources from their respective geographical locations. Volunteers are trained and comfortable using the water testing kits. After the tests are conducted, they are sent to the University of Nebraska for further analysis (University of Nebraska College of Civil and Environmental Engineering, 2022).

Webinars/Online Education

The Nebraska Water Center, in conjunction with the Water for Food Daugherty Global Institute at the University of Nebraska, host various education workshops and webinars online and in person. These events range from pesticide application education to learning about the ecology of Nebraska's rivers.

Daugherty Water for Food Global Institute

The Daugherty Water for Food Global Institute at the University of Nebraska focuses on managing water resources through agricultural and food systems (The Daugherty Water for Food Global Institute, 2022). Though this institute is globally focused, it still is a critical component in Nebraska's water quality improvement efforts. The Daugherty Water for Food Global Institute holds educational workshops and seminars, some of which focus on Nebraska. The institute recently established a water, climate and health initiative and works closely with the Water, Climate, and Health Program toward water quality and health objectives.

Nitrate Working Groups

The Nebraska Nitrate Working Groups were recently founded in order to find commonalities between sectors, organizations, and stakeholders to collectively work to address

water quality issues within Nebraska. These working groups are still in the process of organizing and goal-setting.

Bazile Groundwater Management Area (BGMA)

The Bazile Groundwater Management Area is located within four Natural Resource Districts (NRD's) in Northeast Nebraska. Because of the rising amount of nitrate in domestic wells, this project was founded by local producers and NRD's to address water quality issues. The BGMA created a master plan outlining goals for improving water quality; it was the first federally recognized plan to address nonpoint source pollution in the entire nation. Broadly, the plan's goals are to reduce and eventually eliminate high nitrate in groundwater (Bazile Groundwater Management Area, 2022).

Ongoing Research:

There continues to be ongoing research in the state of Nebraska regarding water quality and its impact on human health. This research is mainly being conducted by the University of Nebraska systems in collaboration with entities outside of the NU system, such as Natural Resource Districts and local producers.

Chapter 3: Methods

Study Design

This study aimed to discover the existing educational material about the hazards of consuming nitrate contaminated drinking water as well as the level of formal training and awareness among health care providers and the deficiencies in those two areas in the medical clinics in Nebraska's counties with highest water levels of nitrate contamination. To collect the needed data, a survey with eight multiple choice questions was developed using Microsoft Forms. The survey was disseminated to participants through a unique weblink as well as in-person meetings. All responses were stored in the Microsoft Forms database. Later, analytical functions were used to do the quantitative analysis.

Sample

We used a targeted convenience sample approach to recruit health care providers in counties with known high nitrate levels in Nebraska to take the survey. Eligible participants for the survey included health care providers and consisted of the following: Medical Doctors, Physician Assistants, Nurse Practitioners, Registered Nurses and Licensed Practical Nurses, in the counties in Nebraska that have the highest rates of nitrate contaminated waters. Participants were identified through online research of healthcare clinics located in these at-risk areas. Health care providers were selected due to their direct contact with the patients and the opportunity to directly discuss this issue with patients during their care visits.

Identification

There are nine (9) at-risk counties in Nebraska with the highest rates of nitrate rates in their water including: Knox, Holt, Pierce, Platte, Merrick, Buffalo, Keith, Kearney and Phelps.

Below is the map used to identify the most at-risk counties (Figure 5).

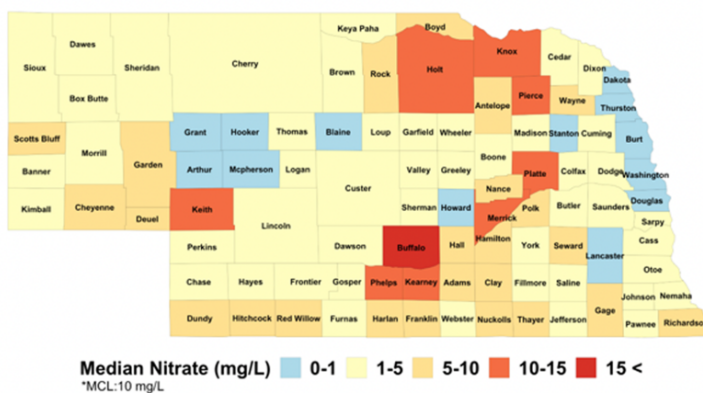


Figure 5. Median nitrate levels by county in Nebraska (Munde, 2019).

Participant recruitment was conducted through communication pathways with clinic managers via email, website clinic contacts forms and in-person recruitment. Throughout these counties, 32 medical clinic managers were asked to distribute the surveys to their medical providers. All responses were anonymous, and this research study did not define in which county the participating providers were located or how many providers from each location completed the survey.

All medical clinic managers were contacted twice to ensure they received the study information and survey link to pass the survey along to the providers and nurses. Survey participant recruitment began February 25th 2022, and the survey closed March 21st, 2022.

Data Collection:

Data for the Nitrate Contaminated Drinking Water Educational Materials Survey was collected in two ways:

1. Via the online Nitrate Contaminated Water Educational Materials Survey that was disseminated to clinic managers to distribute to the providers containing a unique link. We collected 12 survey responses through the online link. We do not know from which clinic the survey responders are from nor do we know how many providers at each clinic completed the survey.
2. In-person meetings with clinic managers. The surveys were introduced, and paper versions of the survey were left at clinics for providers to complete. We collected 15 survey responses through in-person meetings. Data that was collected via in-person meetings was later entered into the online Microsoft Forms database.

Survey Design

The survey began with a brief description of the health effects of consumption of nitrate contaminated drinking water. It followed with questions regarding participant's occupation, level of concern of this topic, level and frequency of water quality and human health education, the patient population each provider serves, current education materials providers obtain, and what materials they would like to obtain to educate themselves and/or their patients.

Statistical Analysis:

With both forms of data collection, we received a total of 27 responses- 12 responses via online link and 15 via in-person meetings. Because the survey was sent to one point of contact (POC) at each clinic, we do not know how many providers the POC forwarded the online surveys to. Therefore, there is not an accurate way to determine a response rate for the online surveys. Eighteen in person meetings were held and we received 15 completed surveys. Therefore, the in-person meetings had a response rate of 83%.

General descriptive statistics were populated by the built-in data analytics to initially summarize the data collected on Microsoft Forms. Descriptive statistics offer basic information of the data set and its variables, as well as how the variables relate to each other. Such statistics were exported into Excel from Microsoft Forms. Later, statistics were analyzed by R and R Studio; data was then organized into various charts and graphs for easy viewing.

Chapter 4: Results

To ensure sufficient coverage, 32 medical clinic managers were contacted to distribute the survey to their healthcare providers. Medical clinics in Knox, Holt, Pierce, Platte, Merrick, Buffalo, Keith, Kearney and Phelps counties were selected as they are the counties with the highest nitrate levels in the state of Nebraska. A total of 27 healthcare providers completed the survey from the 32 clinics contacted. Twelve (44%) of the surveys were completed online, and 15 (56%) of the survey respondents completed hard copy surveys. Respondents included Medical Doctors, Nurses, Nurse Practitioners, Physician Assistants, and Medical Assistants from medical clinics in Nebraska.

Study Population Occupation:

Among the 27 respondents, 10 nurses (specifically Registered Nurses and Licensed Practical Nurses) completed the survey, representing the largest group to respond to the survey (37% of total respondents). The second largest group to complete the survey was Physician Assistants, 8 (30%) respondents. Respondents also included 5 (19%) Nurse Practitioners, 3 (11%) Medical Doctors and 1 (4%) “Other”, consisting of “Medical Assistant”.

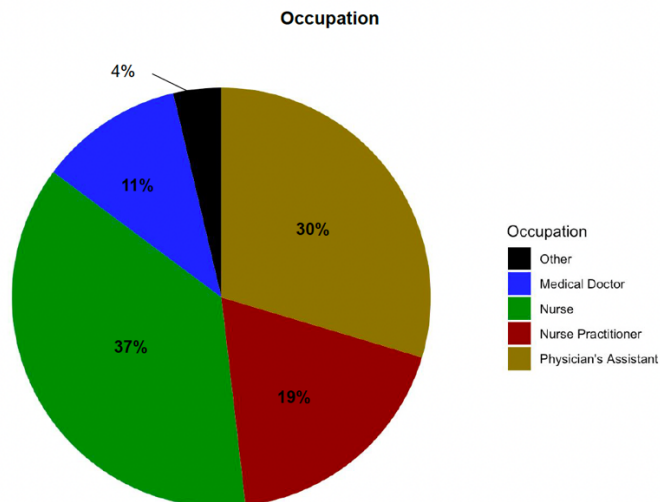


Figure 6. Occupation of respondents

Level of concern of nitrate drinking water contamination and its associated health effects

The results show healthcare providers have various concern levels, but the majority seemed to show a higher level of concern. Around 11% (6) respondents expressed that “I am extremely concerned.”, 18 (67%) of respondents were “Somewhat Concerned”; 4 (15%) were “I am neutral”. Lastly, both “Somewhat not concerned” and “I am not concerned” were 3.7% of respondents (one respondent each.)

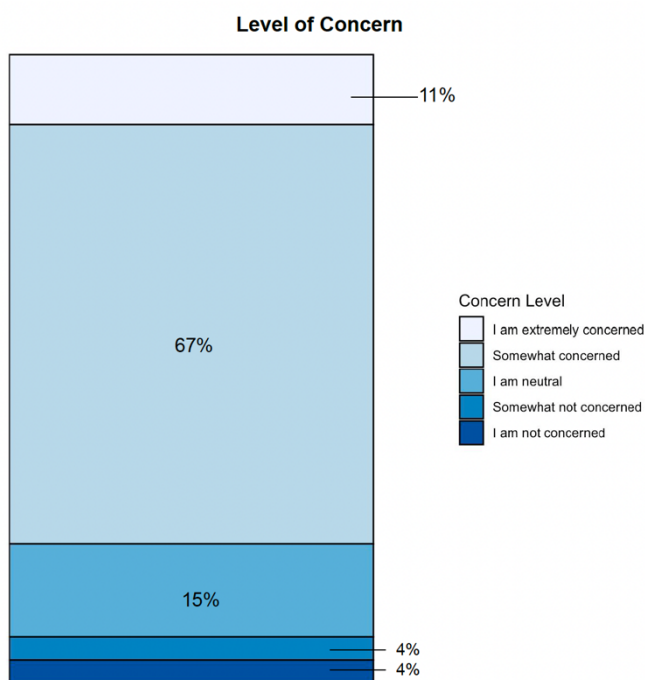


Figure 7. Level of concern of nitrate drinking water contamination and its associated health effects

Amount of Formal Training/Education on the Health Consequences of Drinking Nitrate Contaminated Water

In accordance with the findings from the levels of concerns among the health care providers, we found that most respondents (16, 63%) have no or little formal education and training of the health effects of consuming nitrate contaminated water. Eleven (41%) responded that they “have not received any formal training”. Five (22%) responded they have received “very little training”. Eight (30%) respondents stated they have “received some training”. Two (7%) of respondents have received “a fair amount of training”. Surprisingly enough none of the respondents “received extensive training.”

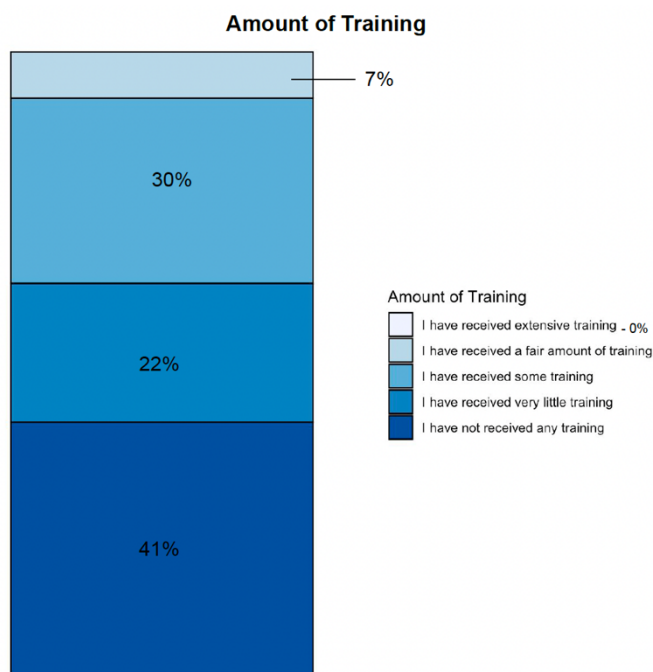


Figure 8. Amount of training on the health consequences of drinking nitrate contaminated water of respondents

Frequency of Training on the Health Consequences of Drinking Nitrate Contaminated Water

Additionally, participants were asked how often they receive formal education and training. Over half of respondents, (58%, 16) stated they have “never had any formal education.” Five (19%) said they have received formal education “once”, and 23% (6) stated they have received it “more than once but not on a regular basis.” None of the respondents reported they receive education “on a regular basis.” Respondents who had received some frequency of education still received training relatively infrequently. No respondents reported they received training and education on a regular basis.

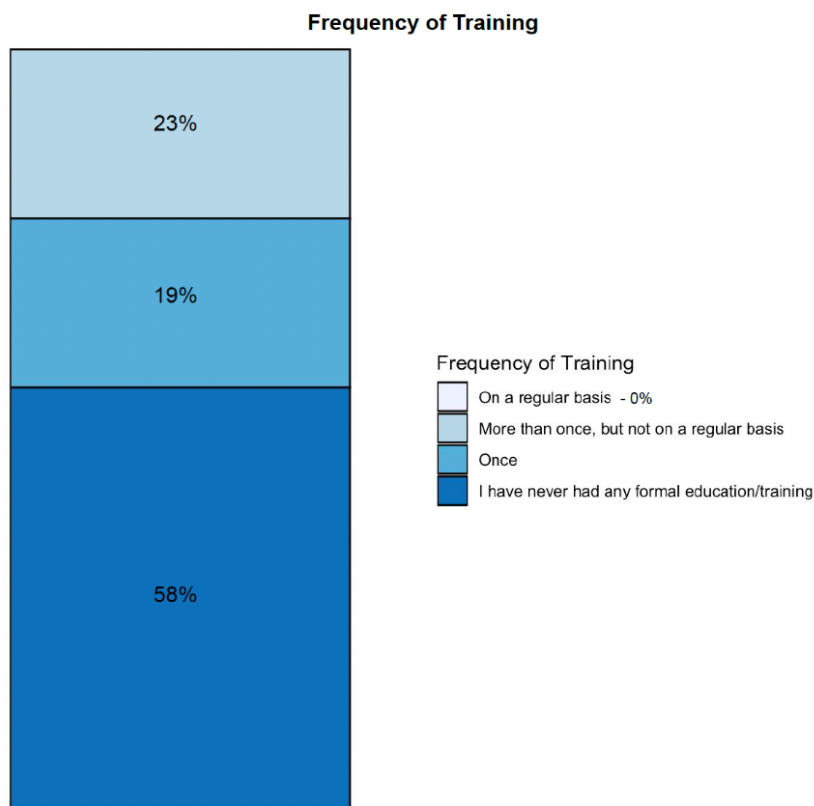


Figure 9. Frequency of training on the health consequences of drinking nitrate contaminated water of respondents

Patient Populations Served:

Many survey respondents serve all populations that are at-risk for developing health effects from consuming nitrate contaminated water. The most common patient population served were pregnant women and their fetuses; 25 out of the 27 respondents serve this population. Young infants less than 6 months of age were the second most served patient population. It is interesting that the top two patient populations both involve fetuses or young infants. Perhaps they actually are the most commonly served patient populations, but possibly providers feel that they are the most at-risk because the fetus and young infant are unable to make their own decisions and should be the most protected.

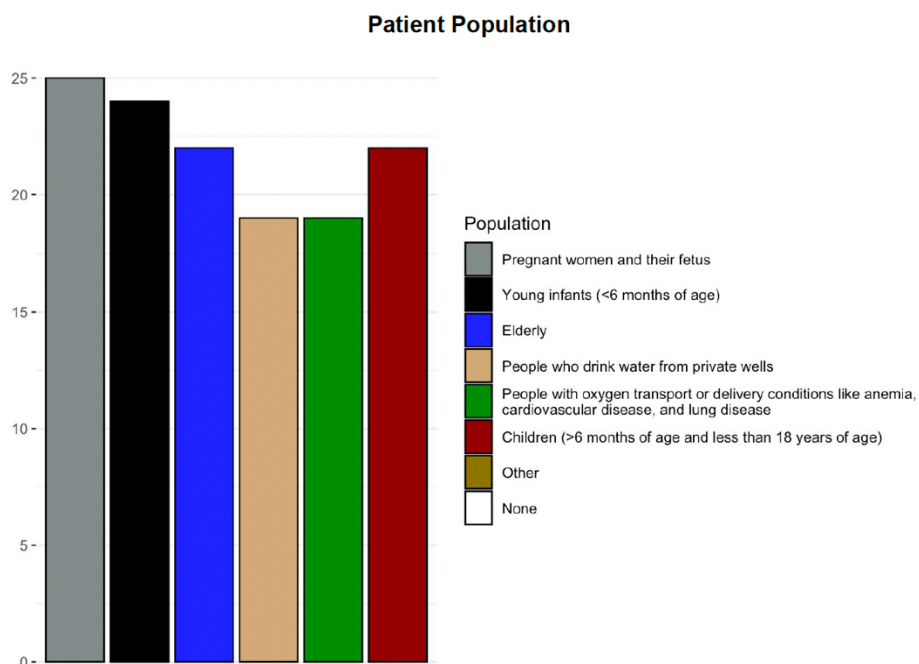


Figure 10. Patient populations served

Educational Materials Requested by Providers to Help Educate Themselves on the Health Consequences of Drinking Nitrate Contaminated Water:

Seventeen out of 27 healthcare providers reported they would like an educational video to help educate them on the health consequences of consuming nitrate contaminated water. Educational videos could be created and sent across the entire state to reach all healthcare providers in all locations. Similarly, continuing education credits could be created and easily distributed across the state because it too is virtual. These findings display that the most effective way to educate healthcare providers would be online educational materials.

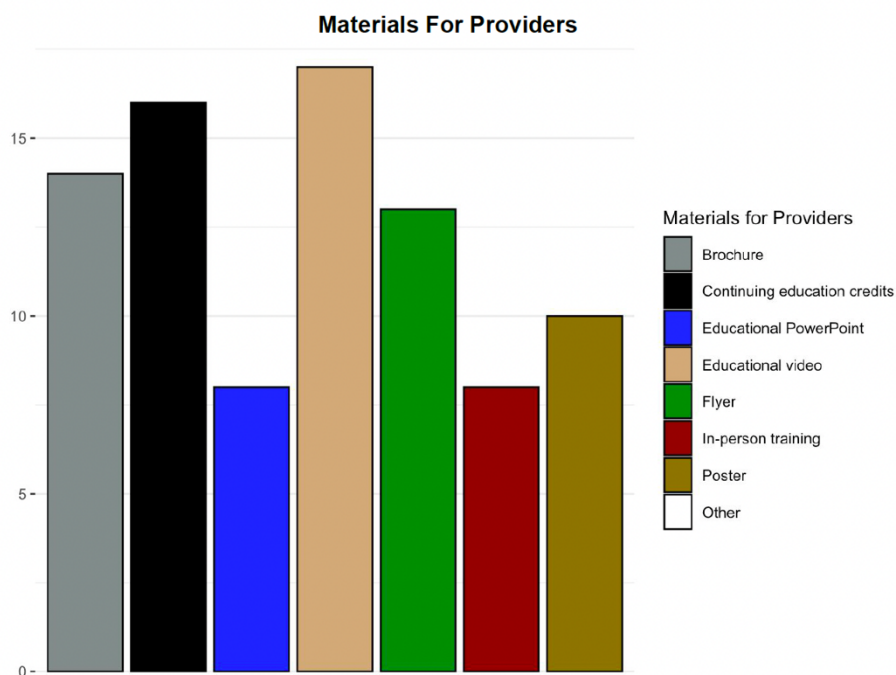


Figure 11. Materials requested by providers to educate themselves about the health consequences of drinking nitrate contaminated water

Educational Materials About the Health Consequences of Drinking Nitrate Contaminated Water Currently Available to Providers

The majority of respondents (15 out of the 27, 56%), reported they currently have no educational materials regarding the health consequences of consuming nitrate contaminated water. This is a major concern because all respondents are from high-risk areas, and they should be informed about the potential health risks in their respective geographical locations. The unavailability of educational materials is putting patient populations' health at risk. The most common available material was online resources. It would be interesting to know what kinds of online resources these respondents feel like are available to them and if they are utilizing them.

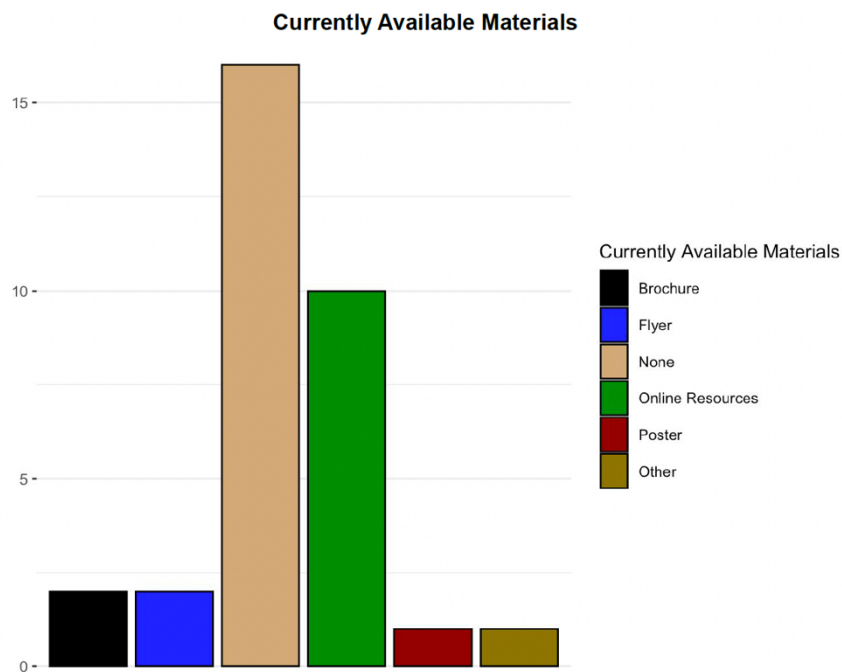


Figure 12. Currently available educational materials about the health consequences of drinking nitrate contaminated water

Educational Materials Requested by Providers to Help Educate Their Patients on the Health Consequences of Drinking Nitrate Contaminated Water:

A majority of healthcare respondents (23 out of 27, 85%) reported they would like to have a brochure to offer their patients to inform them of the health consequences of consuming nitrate contaminated drinking water. The other highly requested materials were flyers and posters. This information displays the desire for hard-copy paper materials that providers can physically give their patients. In the previous question, the data displayed providers either have none or only online materials, and this data suggests that those materials are insufficient.

The “Other” category consisted of requests for prepared social media content on the health consequences of drinking nitrate contaminated water.

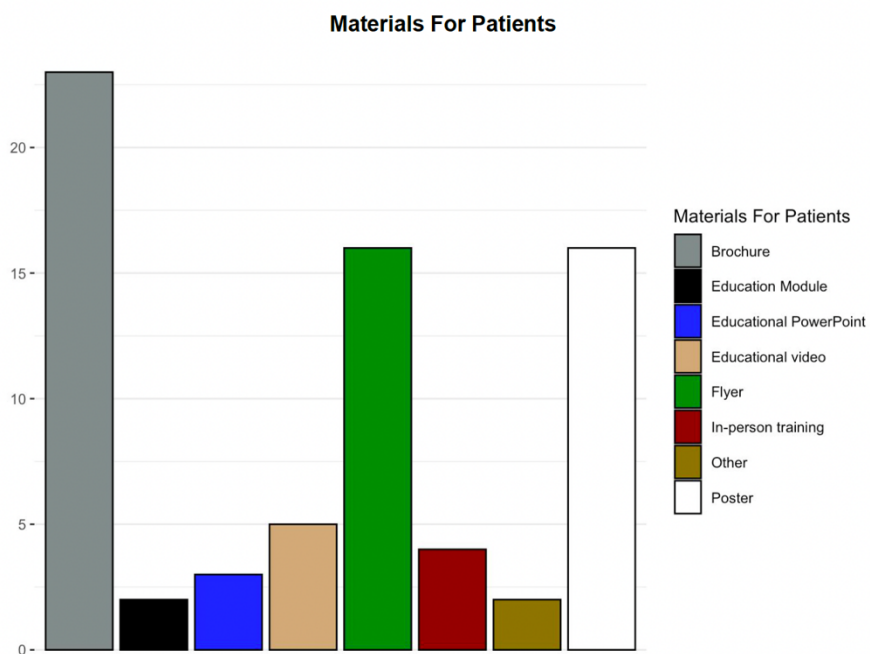


Figure 13. Materials requested to educate patients about the health consequences of drinking nitrate contaminated water

Main Findings:

The overall aim of this project was to discover the current availability of educational materials about the health effects of consumption of nitrate drinking water in medical clinics in Nebraska. The results show that there are several gaps related to education/training and educational materials, including inadequate availability of educational materials for both providers and patients, and the lack of formal training and education of providers on the topic.

Most requested material for providers: Educational Video and Continuing Education Credits

Most requested material for Patients: Brochure, Flyer, and Poster

Amount of training: 63% of providers have had no or little formal education and training of the health effects of consuming nitrate contaminated water.

Chapter 5: Discussion

Consumption of nitrate contaminated drinking water is a serious public health issue that can have significant health consequences. Rural Nebraskans are especially at risk since Nebraska is an agricultural state that widely uses high rates of nitrogen in its farming practices which can easily seep into groundwater. Because nitrogen is a protein for plants, it is commonly used in fertilizers to expedite plant growth and increase crop yields and profits. Farming is a critical part of Nebraska's economy, acquiring 92% of the state's land use and relates to \$7 billion in economic activity (NDA, 2022). Because farming is so prevalent, especially in rural Nebraska, many people do not live within municipality limits. Instead, they live outside municipality limits on farms to raise livestock and farm. Consequently, many rural Nebraskans do not drink municipal water that would require testing under the Safe Drinking Water Act (Safe Drinking Water Act, 1974). Instead, they drink from their own, private domestic wells which are not required to be tested or treated for contaminants. This leaves the population most-at-risk for consuming nitrate contaminated water, because they are surrounded by farming and fertilizing, untested and untreated.

The public health issue of consuming contaminated water is even more pressing because there are known links to consumption of nitrate contaminated water and adverse health outcomes; some of these outcomes include methemoglobinemia, colorectal cancers, thyroid disease, neural tube defects, and other reproductive defects (Ward, et. al, 2018). These are serious health outcomes and can sometimes be fatal. Though the adverse health outcomes are of high severity, there is a lack of adequate legislation to protect the lives of people who rely on and

consume water from private, domestic wells. Nebraska has no state legislation of any kind mandate testing and treatment of private wells.

The lack of formal policy requires population health promotion, through higher rates of awareness and education efforts. Health promotion is a critical part of improving population health, and it is possible to use various avenues to increase health promotion. An effective avenue for this public health issue is using healthcare providers as a vessel to spread education and awareness to their patients, but before we can ensure providers are educating patients, it is important to know if healthcare providers are equipped to do so.

This project aimed to discover the level of concern among health care providers on how nitrate drinking water consumption relates to their patients' health, the level of training and education providers have received on this topic, what current educational materials regarding the health consequences of drinking nitrate contaminated water are accessible to providers, and/or what educational materials they would like to have to better educate themselves and their patients.

This research revealed some interesting results that point to several serious public health issues specific to the state of Nebraska but can also have some national implications. The first result is that many healthcare providers are not formally trained or educated adequately on the health implications of drinking nitrate contaminated water. 63% of healthcare providers responded they have had little to no formal education and training. It is alarming that though drinking nitrate contaminated water can have such serious health consequences, the majority of health providers have never had any formal education or training

The second result relates to types of educational materials regarding the health consequences of consuming nitrate contaminated water are currently available to healthcare providers. Surprisingly, fifteen out of the twenty-seven respondents (56%), said they currently do not have access to any educational material related to the complications or risks of consuming nitrate contaminated drinking water. This is alarming, especially because survey respondents were those who are in the most at-risk areas of Nebraska.

Thirdly, the data collected tells us what educational materials are needed to improve education for both providers and patients. In order for healthcare providers to be able to spread awareness and help educate their patients, it is clear they need appropriate materials to do so.

1. What type of educational materials regarding the health consequences of consuming nitrate contaminated water would healthcare providers like **to best educate themselves**?

To educate patients, health care providers need to fully understand the health consequences of consuming nitrate contaminated water as well. Because the data displayed 63% of health care providers have received little to no formal education and training on how drinking nitrate contaminated water impacts human health, it is clear there is a large deficiency in educational materials or perhaps the relay of the educational materials. The results of the study offer suggestions on how to help close that gap and educate providers. An educational video and/or continuing education credits would likely be the most effective.

2. What type of educational materials regarding the health consequences of consuming nitrate contaminated water would healthcare providers like **to best educate their patients?**

Once health care providers have sufficient knowledge and materials to understand the health consequences of consuming nitrate contaminated water, they will be able to pass along the information to their patients. To do so, healthcare providers will need to be equipped with educational materials that are digestible for the layperson/their patients. Healthcare providers displayed they would prefer hard-copy materials to help educate their patients. The most requested material by far (85%) was a brochure to be able to hand to their patients. The other two materials that were equally requested were flyers and posters.

The presented data highlights that there is currently an all-around lack of education and training materials regarding the health consequences of drinking nitrate contaminated water available for both providers and patients.

Limitations:

There are multiple limitations in this study. The first limitation is related to the study sample. Due to the period and scope of this work, we only included a small group of health care providers using a convenient and snowballing approaches. Despite the known limitations of those approaches, the sample should be a good representation of health care providers in the counties addressed in this study. The second limitation is related to the tool we developed and used. The survey did not include an identifier about where each clinic for each respondent was located. Therefore, it is unknown if the responses represent all 6 counties targeted by our survey.

Lastly, the tool was a simple survey that did not include any demographic questions to help us correlate certain findings to certain groups.

Future Recommendations

This data offers the kinds of materials healthcare providers requested to educate themselves and their patients. The tool is limited in the questions it asked; therefore, the initial next step should be to expand the survey to ask more questions such as from what location is the respondent. and what for the next major step would be to create the educational materials. After, we would distribute the materials to the at-risk clinics.

This data offers the kinds of materials healthcare providers requested to educate themselves and their patients. The tool is limited in the questions it asked; therefore, the initial next step should be to expand the survey to ask more questions such as from what location is the respondent. Following the tool expansion, the next step would be to send the survey to more healthcare clinics and providers. Therefore, we could get a true representative sample which would help make more strategic and financial decisions for material creation and distribution.

The following step would be to identify exactly what kind of content should be provided on the educational materials for medical clinics. This could be achieved by conducting focus groups or creating another follow-up survey to identify the content and how the content should be presented. After these steps, content and material should be developed and distributed in the requested avenues the research and surveys display.

Expanding upon this research is key to continue to increase education and awareness of the health consequences of consuming nitrate contaminated water. This survey could be

expanded to all healthcare clinics in Nebraska, to get a larger view of needs in the state and ensure all healthcare providers and clinics have the materials they need to educate their patients. Additionally, the survey could be adjusted to ask other types of educators in the state, such as schoolteachers in at-risk areas, the same kinds of questions and equip them with educational materials as well.

Conclusion:

With 92% of Nebraska's land being used for agriculture and farmers using high rates of nitrogen in their fertilizer, drinking water wells are at a very high risk for being contaminated with nitrate (NDA, 2022). Drinking nitrate contaminated water can have very serious health consequences such as methemoglobinemia, certain cancers, and birth defects. 20% of Nebraskans drink from private wells, which are predominately located in rural and agricultural areas and there is no policy that requires them to be tested. Even more concerning, drinking wells in rural areas are the most at-risk for contamination due to the high amount of farming and its chemicals.

Due to the lack of legal policy currently in place, education and awareness are critical to help reduce the amount of consumption of nitrate contaminated water. People must first be aware of the issue at-hand before they are able to make a change in behavior. Healthcare providers are a trusted source of health information and have direct contact with much of the population. Therefore, healthcare providers were chosen as the survey sample population. The results describe the need of educational materials for both providers and their patients. The results of the data provide sufficient next steps for the kinds of materials should be created for healthcare providers and their patients.

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Appendix A:

Nitrate Contaminated Drinking Water Educational Materials Survey

University of Nebraska Medical Center
College of Public Health
Department of Health Services Research and Administration

Consumption of nitrate contaminated drinking water has been linked to many adverse health effects such as methemoglobinemia, preterm birth issues, birth defects, pediatric cancers, and adult cancers. Concerningly, Nebraska has widespread nitrate contamination of drinking water sources. This survey, conducted by the University of Nebraska Medical Center- College of Public Health, is designed to capture data about the availability and types of educational materials providers and their patients currently need for them to understand the potential health effects of consumption of nitrate contaminated drinking water. The results of the survey will assist in the production and distribution of educational materials.

All responses are anonymous. This survey will take 5 minutes or less.

1. What is your occupation?

- Medical Doctor
- Physician's Assistant
- Nurse Practitioner
- Nurse
-

2. On a scale of 1-5, how concerned are you with nitrate contaminated drinking water as it relates to the health of your patient population?

I am extremely concerned	Somewhat concerned	I am neutral	Somewhat not concerned	I am not concerned
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

3. On a scale of 1-5, please indicate how much formal education and training you have had on the adverse human health effects associated with consumption of nitrate contaminated drinking water?

I have received extensive training	I have received a fair amount of training	I have received some training	I have received very little training	I have not received any training
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

4. If you have received any formal education/training on the adverse human health effects of consuming nitrate contaminated water, please indicate the frequency with which you have received training.

On a regular basis	More than once, but not on a regular basis	Once	I have never had any formal education/training
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

5. Which of the following patient populations you serve are at risk for developing adverse health effects from consuming nitrate contaminated drinking water? (Select all that apply)

- Pregnant women and their fetus
- Young infants (<6 months of age)
- Children (>6 months of age and less than 18 years of age)
- People with oxygen transport or delivery conditions like anemia, cardiovascular disease, and lung disease
- People who drink water from private wells
- Elderly
- None
- Other

6. What education materials **would help educate you** on the adverse health effects of consumption of nitrate contaminated drinking water? (Select all that apply)

- Educational video
- Flyer
- Brochure
- In-person training
- Educational PowerPoint
- Poster
- Continuing education credits
- Other

7. Please indicate the type(s) of educational materials **currently available to you** and that you can use to inform your patient population on the adverse health effects associated with consumption of nitrate contaminated drinking water. If you do not have access to any educational materials on this topic, please indicate as such.

- Flyer
- Brochure
- Poster
- Online Resources
- None
- Other

8. What type(s) of education materials **would best inform your patients** on the adverse health effects of consuming nitrate contaminated drinking water? (Select all that apply)

- Educational video
- Flyer
- Brochure
- In-person training
- Educational PowerPoint
- Education Module
- Poster
- Other