

UNIVERSITY OF WISCONSIN-LA CROSSE

Graduate Studies

KNOWLEDGE, AWARENESS, AND PRACTICES RELATED TO NITRATE WELL
WATER TESTING AMONG PRIVATE WELL OWNERS
IN LA CROSSE COUNTY, WISCONSIN

A Chapter Style Thesis Submitted in Partial Fulfillment of the Requirements for the
Degree of Master of Public Health

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Master of Public Health in Community Health Education

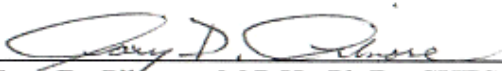
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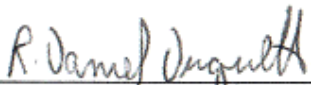
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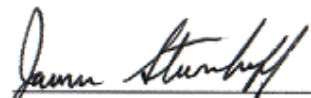
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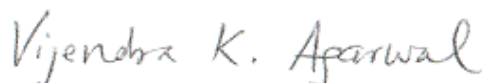
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ABSTRACT

O'Donnell, M. Knowledge, awareness, and practices related to nitrate well water testing among private well owners in La Crosse County, Wisconsin. Master of Public Health-Community Health Education, May 2010. pp. 90 (G.D. Gilmore).

Nitrate, a naturally occurring ion in the environment is one of the most common causes of contaminated groundwater. The primary concern with ingestion of nitrate contaminated groundwater is a condition called infant methemoglobinemia and recent studies have found associations between exposure to nitrate contaminated groundwater, cancer, and reproductive and developmental outcomes. Because testing for nitrate is the responsibility of the private well owner, efforts to assess knowledge, awareness, and practices related to nitrate well water testing for the purposes of developing or improving educational efforts was investigated by use of a mailed survey among randomly selected private well owners in La Crosse County, Wisconsin. A total of 165 (out of 500) surveys were returned and analyzed. Awareness of nitrate well water testing (yes or no) and tested for nitrate (yes or no) was cross tabulated and found to be significant (Asymp. Sig. 2-sided 0.000, Pearson chi-square value 37.73). Among those that were aware of nitrate well water testing, 69% had tested their well water for nitrate and 31% had *not* tested their well water for nitrate suggesting the need for educational efforts, particularly for high risks groups. In addition, efforts aligned with encouraging regular testing practices should be a priority.

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TABLE OF CONTENTS

	PAGE
ABSTRACT.....	iii.
ACKNOWLEDGEMENTS.....	iv.
LIST OF TABLES.....	vii.
LIST OF FIGURES.....	viii.
LIST OF APPENDICES.....	ix.
CHAPTER ONE: INTRODUCTION TO THE PROBLEM	
Statement of the Problem.....	1
Need for the Study.....	4
Purpose of the Study.....	6
Delimitations.....	7
Limitations.....	7
Assumption.....	7
Definition of Terms.....	7
CHAPTER TWO: REVIEW OF RELATED LITERATURE	
Introduction.....	9
Nitrate in the Environment.....	9
Impact on Health.....	13
Well Water Testing.....	20
Prevention and Control.....	22

	PAGE
 CHAPTER THREE: METHODOLOGY	
Introduction.....	26
Study Participants.....	26
Instrumentation.....	27
Validity.....	27
Readability.....	28
Procedures.....	28
Statistical Analysis.....	29
 CHAPTER FOUR: RESULTS	
Introduction.....	30
Content Validation.....	30
Pilot Study.....	31
Survey Results.....	31
 CHAPTER FIVE: CONCLUSIONS AND RECOMENDATIONS	
Summary.....	46
Conclusions.....	46
Recommendations.....	50
 REFERENCES.....	 55
APPENDICES.....	61

LIST OF TABLES

TABLE	PAGE
1. Summary: Demographic Information.....	33
2. (a) Frequency of the top three rankings to obtain information about..... well	38
(b) Frequency of the top three rankings to obtain information about..... well water testing	38
3. Summary: Rankings of use of sources.....	39
4. Summary: What prompted testing well water for nitrate.....	41
5. Summary: Reasons for not testing for nitrate.....	42
6. Summary: Greatest source of contamination.....	43

LIST OF FIGURES

FIGURE	PAGE
1. How survey respondents learned about nitrate well water testing.....	34
2. Most important reasons to test well water for nitrate among..... survey respondents	35
3. How survey respondents got information about their private well.....	37
4. Last time well water was tested for nitrate.....	40
5. Awareness and testing.....	44

LIST OF APPENDICES

	PAGE
Appendix A. GIS Map, La Crosse County Lab..... Nitrate Levels for Last Ten Years	61
Appendix B. Research Question and Survey Item Alignment.....	63
Appendix C. Content Validation Jury Panel.....	68
Appendix D. Cover Letter and Survey..... “Assessment of Well Water Testing for Nitrate”	70
Appendix E. Content Validation Jury Results Summary.....	76
Appendix F. Awareness and Tested Crosstabulation Results.....	80

CHAPTER ONE

INTRODUCTION TO THE PROBLEM

Statement of the Problem

Chemical contaminants with potentially toxic effects in public and private water supplies are an increasing concern because of the risks to human health. Nitrate, a naturally occurring ion in the environment is one of the most common causes of contaminated groundwater. It is found in plants and vegetables at varying concentrations and small amounts of nitrate, less than 2 milligrams per liter (mg/L), are naturally found in water, therefore higher levels indicate contamination. Nitrate in groundwater can originate from several sources, such as fertilizers, animal wastes, decaying plant debris, municipal sewage treatment systems, and septic tanks (Wisconsin Groundwater Coordinating Council, Report to the Legislature, 2006). Due to the increased use of artificial fertilizers, disposal of animal wastes, and changes in land use, levels of groundwater nitrate have been increasing over the last 20 years (WHO, 2007).

It is estimated that 22 percent of domestic wells in agricultural areas in the United States exceed the U.S. Environmental Protection Agency maximum contaminant level for nitrate in drinking water of 10 mg/L nitrate-nitrogen (as cited in Ward et al.,

2005). In the United States, groundwater is the main supply for many rural communities (Nolan et al., 1997) and an estimated 42% of the United States population uses groundwater as their drinking water supply (Hutson et al., 2004). Agriculture areas are particularly susceptible to groundwater contamination due to agricultural practices leading to an accumulation of nitrogen and higher levels year after year (Nolan et al., 1997). Several factors increase one's risk for exposure to nitrate contaminated groundwater. Groundwater from shallow wells (less than 100 feet below the land surface), in areas with well draining soil and high nitrogen inputs, and groundwater in agricultural areas are all increased risk factors for exposure to nitrate contaminated groundwater (Manassaram et al., 2006). The Midwest area of the United States has a high risk of groundwater contaminated by nitrate (Nolan et al., 1998) and because Wisconsin is an agricultural state the use of fertilizer contributes greater to contamination of groundwater by nitrate.

Ingestion of nitrate contaminated water has serious health effects. Nitrate has been implicated in methemoglobinemia (MetHb), commonly called "blue baby syndrome," a condition which results from ingested nitrate binding with hemoglobin in the blood and interfering with its oxygen carrying capacity (Ward et al., 2005). Because infants under six months of age lack an enzyme called NADH-cytochrome b₅ reductase, which converts methemoglobin back into hemoglobin, this age group is particularly susceptible and if levels of MetHb are high enough, cyanosis can result (Avery, 1999). The United States Environmental Protection Agency (U.S. EPA) set the federal

maximum containment level (MCL) for nitrate-nitrogen at 10 mg/L as the primary method to prevent infant methemoglobinemia. However, recent debate has arisen regarding the suitability of the current MCL standard which is complicated by the fact that methemoglobinemia is not a reportable condition in addition to lack of data about exposure levels above the MCL standard (Manassaram et al., 2006). Nonetheless, infants continue to be diagnosed and treated for methemoglobinemia (Knobeloch et al., 2000). Recent cases of methemoglobinemia (1998 & 1999) in Wisconsin suggest that it is still an infant health concern in rural Wisconsin (Knobeloch et al., 2000).

Susceptibility to nitrate induced health effects in adults is mediated by bacteria in the mouth and gastrointestinal system and risk of methemoglobinemia depends on two factors, the level of nitrate contamination and number of enteric bacteria (U.S. EPA, Integrated Risk Information System). Recent studies have generated concern about the link between nitrate and cancer. Nitrate is a precursor in the formation of N-nitroso compounds (NOC) which are known animal carcinogens (Schottenfeld & Fraumeni, Jr., 2006). Results from epidemiological studies about nitrate contaminated groundwater intake and cancer are mixed, but several studies have found positive associations between drinking water nitrates and gastric cancer (Morales-Suarez-Varela et al., 1995 & Yang et al., 1998), prostate cancer (Morales-Suarez-Varela et al., 1995), bladder cancer and ovarian cancer (Weyer et al., 2001) and non-Hodgkin lymphoma and colorectal cancer (Gulis, Czompolyova & Cerhan, 2002).

Possible reproductive and developmental outcomes from maternal exposure of nitrate contaminated drinking water are suggestive at this time. The relationship between

methemoglobinemia and abortions was evaluated early on by Schmitz (1961) and showed that higher levels of blood methemoglobinemia were observed in women who threatened to abort or aborted, however; the report indicated that even though nitrates are the most common cause of methemoglobinemia, other causes may have contributed (Schmitz, 1961). More recently, a cluster of spontaneous abortions in LaGrange County Indiana may have been related to elevated levels of nitrate (greater than 19.0 mg/L) in the drinking water (MMWR, 1996).

A study of agrichemicals in surface water and birth defects in the United States showed an association between increased risk of birth defects and increased levels of nitrates (and other chemicals) in surface water for the months of increased risk (April-July) (Winchester, Huskins, & Ying, 2009). Another study by Dorsch et al., (1984) found an increased risk of a malformed child among women who consumed groundwater and more importantly, a parallel relationship between increased nitrate concentration and risk for women; a threefold and fourfold increase in risk for women who drank water containing 5-15 parts per million (ppm) of nitrate and greater than 15 ppm (ppm equivalent to mg/L) (Dorsch et al., 1984). A population-based case-control study out of California demonstrated an increased risk for anencephaly in babies whose mothers lived in an area with nitrate in drinking water exceeding the MCL (above 45 mg/L) (Croen, Todoroff, & Shaw, 2001).

Need for the Study

With a high proportion of dairy and beef farming, nitrate in Wisconsin is the most widespread groundwater contaminant and is increasing in severity (Wisconsin

Groundwater Coordinating Council, Report to the Legislature, 2006). A 1994 study estimated that 9 to 14 percent of private wells in Wisconsin exceed the nitrate standard and another study (1997) estimated exceedance rates of 17 to 26 percent for wells in agricultural areas (Wisconsin Groundwater Coordinating Council, Report to the Legislature, 2006). In Wisconsin, Calumet, Columbia, Dane, La Crosse, and Rock counties are identified as having the highest percent exceedances with 20% to 30% of the private well samples above the 10 mg/L standard (Wisconsin Groundwater Coordinating Council, Report to the Legislature, 2006). Because of the exchange of old and new groundwater, it is likely that groundwater is being replenished with higher nitrate levels resulting in the likelihood that average nitrate concentrations in Wisconsin's groundwater will increase (Chern, Kraft, & Postle, 1999).

Public water systems are required to be tested for nitrate, but private water systems or domestic well systems are not regulated, therefore leaving the responsibility of testing well water for nitrate to the private well owner. A Minnesota survey of well owners showed that of well owners with nitrate levels over 10 mg/L, 31 percent were unaware of the contamination and took no remediation actions (Lewandowski et al., 2008). Based on those results, the authors argue for the continued need for educational programs (Lewandowski et al., 2008). Similarly, results from a 1999 (Schubert et al., 1999) study about public response to nitrate contaminated water in Wisconsin, support the need for on-going education for private well owners especially for women of childbearing age. In addition, women of childbearing age who live on or near farms and with old or shallow wells were identified target populations for special educational efforts

(Schubert et al., 1999). An important finding of the Schubert (1999) study indicated that the majority of families with nitrate contaminated water used it as their primary drinking water source and were not taking any action to reduce exposure.

Purpose of the Study

The purpose of the study was to assess knowledge, awareness, and practices related to nitrate well water testing among private well owners in La Crosse County, particularly how private well owners become aware of nitrate well water testing and what prompts and impedes them in testing their well water. The study aims to answer the following research questions:

1. How do private well owners become aware of nitrate well water testing?
2. What is the understanding about the cause of groundwater contamination among private well owners?
3. What sources serve as information for private well owners to learn about their private well?
4. What prompts private well owners to test for nitrate?
5. What barriers prevent private well owners from testing their private well water for nitrate?
6. What percent of private well owners think it is important to test their private well water for nitrate and why?
7. To what degree are private well owners concerned about nitrate groundwater contamination?

Delimitations

The study population will be delimited to homeowners of private wells in La Crosse County. Private well water sampling and testing of the participants well water during the time of the survey was not a feature of this study.

Limitations

Participation in the study was voluntary and refusal to participate in the study was a limitation. In addition, participant self-report and recall were limitations as well. These were limitations due to the subjective nature of the survey information.

Assumptions

The format of the survey was reliant on self-reporting and therefore, it is assumed that the study participants were honest and accurate in their survey responses.

Definition of Terms

The following terms used in the study are defined below:

Agrichemicals: also known as agrochemicals, is the general term describing various chemical products used in agriculture including fertilizers, pesticides, and other chemical growth agents (<http://www.chem-online.org/agrochemical.htm>)

Anencephaly: a defect in the neural tube during fetal development that occurs when the neural tube fails to close resulting in the absence of brain, skull, and scalp development (<http://www.ninds.nih.gov/disorders/anencephaly/anencephaly.htm>)

Groundwater: water beneath the surface of the ground in a saturated zone or water table, the level below the soil or rock filled with water (Groundwater, Wisconsin's Buried Treasure, PUBL-DG-055-06)

Maximum Containment Level (MCL): The highest level of contaminant allowed in drinking water (<http://www.epa.gov/waterscience/criteria/drinking/dwstandards.html>)

Nitrate: (NO₃⁻) is a naturally occurring water soluble molecule in the environment made up of nitrogen and oxygen and is formed when nitrogen and ammonia or other sources combine with oxygenated water (<http://www.dnr.state.wi.us/org/water/dwg/nitrate.htm>)

Methemoglobinemia (MetHb): a condition in which the ability of hemoglobin to carry oxygen in the blood is reduced resulting in the inability to carry oxygen effectively to body tissues (<http://www.nlm.nih.gov/medlineplus/ency/article/000562.htm>)

Private Well: a well serving one home maintained by the owner (Groundwater, Wisconsin's Buried Treasure, PUBL-DG-055-06)

CHAPTER TWO

REVIEW OF RELATED LITERATURE

Introduction

Nitrate, a naturally occurring ion in the environment is one of the most common causes of contaminated groundwater. Nitrate is primarily used in inorganic fertilizers, but is also used as a food preservative and oxidizing agent in the chemical industry (Zuane, 1997). Exposure to nitrates can occur as a result of natural low levels in the soil, air, and water and higher nitrate concentrations and exposure can occur where fertilizers are used, in deposits of decayed animal and plant matter, sludge or refuse leakage, and industrial discharge (Zuane, 1997). Dietary intake of nitrates is estimated at 100 mg/day, with 85-90 percent coming from the ingestion of vegetables (e.g., beets, spinach) and 9 percent from cured meats (Zuane, 1997).

Nitrate in the Environment

Nitrogen plays an important role in the environment and the nitrogen cycle is necessary for soil and water as it relates to agriculture. Nitrogen can form a variety of compounds and is biologically and microbiologically induced by the processes of fixation, ammonification, synthesis, nitrification, and denitrification (Canter, 1997). Soil

acts as a reservoir for nitrogen and through ammonification, the change from organic nitrogen to the ammonium form by microorganisms; an absorbable form is created for plant growth (Bundy et al., 2005 & Canter, 1997). When microorganisms continue to convert ammonium to nitrite, then to nitrate through nitrification, the potential for groundwater contamination exists. Unlike ammonium which binds to soil, nitrate does not bind to soil and leaches through it making it soluble in water (Bundy et al., 2005).

Nitrate concentrations in surface and groundwater in the United States are naturally present at levels below 4mg/L, with levels exceeding 20 mg/L in about 3 percent of surface waters and 6 percent of ground water (WHO, 2007). Nationally, the risk of nitrate contamination is the highest in the Midwest and parts of the West and Northeast coasts due to the high nitrogen input and high aquifer vulnerability, characterized by well-drained soils and low woodland to cropland ratio (Nolan et al., 1998). A survey of water quality from domestic wells in nine Midwest States concluded that out of approximately 5,520 water samples, nitrate was detected in 65.4 percent of the samples with 13.4 percent exceeding the MCL of 10 mg/L, while the mean and range nitrate levels were 8.4 mg/L and non-detectable to 266 mg/L (CDC & NCEH, 1998). Further, a survey of nitrate contamination in Iowa found that 18.3 percent of rural drinking water wells exceeded the MCL for nitrate (Kross et al., 1993). More specifically, with wells less than 15 m deep, nitrate levels exceeding 10 mg/L were found in 35 percent of wells (Kross et al., 1993).

The main factors responsible for the increasing levels of nitrate in groundwater

are the increased use of artificial fertilizers, disposal of wastes, and changes in land use (WHO, 2007). In Wisconsin, groundwater supplies 70 percent of the water used in households and supplies 608 cities and villages with municipal water (Chern, Kraft, & Postle, 1999). A well can become contaminated from a variety of sources, naturally occurring or human induced and those sources can be near the well or because of groundwater movement, at a distance (Simpson, 2004). Those sources include fertilizers, animal wastes, decaying plant debris, municipal sewage treatment systems, and septic tanks (Wisconsin Groundwater Coordinating Council, Report to the Legislature, 2006). A study of fertilizer application and nitrate groundwater contamination in Iowa showed that after 26 years of fertilizer application, nitrate levels in groundwater increased from 5 ppm (ppm equivalent to mg/L) to 23 ppm (as cited in Chern, Kraft, & Postle, 1999) suggesting that fertilizer application has a significant impact on nitrate groundwater contamination over time. Of the 2040 million pounds of nitrogen deposited on Wisconsin's surface annually, 80 percent originates from agricultural sources, including legumes (29 percent), manure (28 percent), and commercial fertilizer (23 percent) (Shaw, 1994 & Chern, Kraft, & Postle, 1999).

As previously mentioned, a 1994 study estimated that 9 to 14 percent of private wells in Wisconsin exceed the nitrate standard and another study (1997) estimated exceedance rates of 17 to 26 percent for wells in agricultural areas (Wisconsin Groundwater Coordinating Council, Report to the Legislature, 2006). In Wisconsin, Calumet, Columbia, Dane, La Crosse, and Rock counties are identified as having the

highest percent exceedances with 20% to 30% of the private well samples above the 10 mg/L standard (Wisconsin Groundwater Coordinating Council, Report to the Legislature, 2006).

With the use of laboratory data and the application of geographic information systems (GIS), ten years of nitrate well water test data for La Crosse County was used to create a map showing nitrate levels in La Crosse County (Sawvell & laboratory staff, 2010, Appendix A). The nitrate results were broken down into three levels, green indicating 0-1.99 mg/L nitrate (safe), yellow indicating 2-10 mg/L nitrate (EPA Preventative Action Level), and red indicating greater than 10 mg/L nitrate (MCL). Based on this map, there are potential areas of concern. Overall, the western side of the county has higher levels of nitrate shown by the red indicator dots, which is likely related to the sandy soils, gravel aquifer, and shallow water table in those areas (D. Sawvell, personal communication, March 25, 2010). Consequently, those areas are highly susceptible to naturally occurring and human-induced contaminants (Kassulke & Chern, 2006). Areas of concern include the Town of Holland located northwest of the Village of Holmen and the Town of Onalaska located west of Holmen; both areas are surrounded by farm land. Further, the Town of Onalaska located north of the City of Onalaska and Brice Prairie are both areas with high nitrate levels based on testing results and are surrounded by marshland and shallow water bodies. Lastly, the Town of Campbell, south of Brice Prairie along the Mississippi River is an area with some red, but mostly yellow indicator dots, representing nitrate testing results between 2-10 mg/L.

Impact on Health

The primary concern with ingestion of nitrate contaminated water is methemoglobinemia, a condition of particular concern for infants under six months of age. Ingested nitrate is converted to nitrite ions that oxidize the ferrous iron in hemoglobin resulting in an inability to bind oxygen and a decreased oxygen carrying capability of the blood (Greer & Shannon, 2010). The United States Environmental Protection Agency (U.S. EPA) set the federal maximum containment level (MCL) for nitrate-nitrogen at 10 mg/L as the primary method to prevent infant methemoglobinemia. However, recent debate has arisen regarding the suitability of the current MCL standard which is complicated by the fact that methemoglobinemia is not a reportable condition in addition to the lack of data about exposure levels above the MCL standard (Manassaram et al., 2006).

Considerations supporting a higher MCL include (Fan & Steinberg, 1996):

- the lack of documented health problems at low levels
- infant methemoglobinemia cases in the United States were reported at levels above the MCL
- some of the cases attributed to nitrate have not been substantiated

In contrast, considerations for a lower MCL include (Fan & Steinberg, 1996):

- deaths in other countries have occurred at nitrate levels below the MCL
- the potential worst health effect (death) support a conservative approach
- the margin between no observed effect level and low observed effect level is narrow

Further complicating the issue is the nutritional status of individuals, particularly, dietary sources of nitrate and ascorbic acid (vitamin C) intake, which acts as a protective agent and the lack of reporting requirements and possible misdiagnosis of infant methemoglobinemia (Fan & Steinberg, 1996). Thus, a better understanding of the factors that lead to methemoglobinemia and the interactions of those factors and the conditions under which exposure takes place is needed (Ward et al., 2005).

The role of nitrates as the primary cause of infant methemoglobinemia are being questioned by those that support an association between gastrointestinal illness in infants and symptoms of methemoglobinemia, suggesting, that gastrointestinal illness or infection may play a role in its development (Fewtrell, 2004). Avery (1999) states that gastrointestinal illness can lead to methemoglobinemia without exposure to high-nitrate drinking water and several studies have concluded that enteric infections caused by contaminated (bacteria) wells may lead to an increase in endogenous production of nitrate in infants with no apparent exogenous agents (Ward et al., 2005), however; infant methemoglobinemia is complicated by many other factors, such as dietary intake, the consumption of antioxidants, inherited enzyme deficiencies, and medication use (as cited in Ward et al., 2005, Knobeloch et al., 2000).

Two recent cases (1998 & 1999) of infant methemoglobinemia in rural Wisconsin were reported with private well water nitrate concentrations in the range of 22.9 to 27.4 mg/L and one fatal case (1986) in rural South Dakota of progressive cyanosis in an infant was from a private well with a nitrate concentration of 150 mg/L (Knobeloch et al., 2000). Although most infant methemoglobinemia cases occur with

nitrate levels exceeding the MCL, a 1992 case in Wisconsin points out the potential narrow margin between no-effect and low-effect levels of nitrate and the synergistic effects of nitrate and other metal contaminants. In the 1992 Wisconsin case, the infant was hospitalized for methemoglobinemia and the water used for drinking and food preparation was filtered by a reverse osmosis system and contained 9.9 mg/L nitrate, while the well contained 58 mg/L nitrate (MMWR, 1993). Additionally, the filtered water contained 7.8 mg/L copper (EPA MCL for copper in drinking water is 1.3 mg/L) (MMWR, 1993) suggesting that metal contamination may facilitate the adverse effects of nitrate.

Recent studies have generated concern about the link between nitrate and cancer. Nitrate is a precursor in the formation of N-nitroso compounds (NOC) which are known animal carcinogens (Schottenfeld & Fraumeni, Jr., 2006). NOC's are formed by the chemical interaction of nitrite (derived from ingested nitrate) with amines and amides in the stomach (Ward et al., 2003). Results from epidemiological studies about nitrate contaminated groundwater intake and cancer are mixed, but several studies have found positive associations between drinking water nitrates and gastric cancer (Morales-Suarez-Varela et al., 1995 & Yang et al., 1998), prostate cancer (Morales-Suarez-Varela et al., 1995), bladder cancer and ovarian cancer (Weyer et al., 2001) and non-Hodgkin lymphoma and colorectal cancer (Gulis, Czompolyova & Cerhan, 2002).

A matched case-control study about gastric cancer mortality and drinking water nitrates for public water supplies support a positive association (Yang et al., 1998) and a study of 258 municipalities in Valencia, Spain found an increased cancer rate with

increased nitrate exposure, specifically, in populations with nitrate levels above 50 mg/L of which the relative risk for gastric cancer in the 55-75 age group was 1.91 and 1.81 for males and females ($p < 0.05$) (Morales-Suarez-Varela et al., 1995). In contrast, a death certificate based matched case control study in Wisconsin found that death associated with gastric cancer was not significantly associated with nitrate exposure from any water source, public or private (Rademacher, Young, & Kanarek, 1992). An ecological study in Slovakia examining a 20 year period of nitrate levels in public water supplies and stomach cancer incidence found a weak positive association among women, though not statistically significant (Gulis, Czompolyova & Cerhan, 2002). The authors noted that approximately 78 percent of the study population had average nitrate levels above 10 mg/L (Gulis, Czompolyova & Cerhan, 2002). A retrospective hospital-based case control study in Germany examining life style aspects found a significant association with stomach cancer risk for those who had a history of well water use or use of a non-centralized water supply (Boeing et al., 1991).

Several studies have found an association between non-Hodgkin's lymphoma (NHL) and nitrate in drinking water. A 1987 ecological study in Nebraska found a twofold increased incidence for non-Hodgkin's lymphoma in counties with greater than 20 percent of the wells contaminated with nitrate (greater than 10 ppm) and in counties with intense fertilizer application, leading the authors to suggest that NHL in Nebraska may be related to fertilizer and or possible pesticide use and consequential groundwater contamination (Weisenburger, 1990). An ecological study of municipal drinking water and NHL in Slovakia found a positive association (Gulis, Czompolyova & Cerhan,

2002). Another study examining long-term consumption of community water (1947-1979) and risk of non-Hodgkin's lymphoma found that higher quartile nitrate levels (greater than 4 mg/L nitrate-nitrogen) were positively associated with risk among men and women (OR= 2.0; 95% confidence interval 1.1-3.6) (Ward et al., 1996), yet another study done in Minnesota linking residential histories to community water records over a 28 year period found no association between NHL and the range of nitrate exposure (0.1-7.2 mg/L) (Freedman et al., 2000). A similar 2006 study found no association with the highest quartile of drinking water nitrate (greater than 2.90 mg/L) leading the authors to conclude that drinking water nitrate levels below 3 mg/L were not associated with NHL risk; however, a limitation of the study was the inability to evaluate higher nitrate levels as noted by the authors (Ward et al., 2006).

Cancer incidence in a cohort of 21,977 women in Iowa that were age 55-69 and used the same water supply for more than 10 years was analyzed against nitrate levels of municipal water supplies divided into three quartiles 0.36, 1.01, and 2.46 mg/L nitrate-nitrogen and found positive associations for bladder cancer and ovarian cancer and an inverse association for uterine cancer and rectal cancer (Weyer et al., 2001). Likewise, a death certificate based case control study examining bladder cancer mortality and nitrate exposure in municipal water systems in Taiwan found a significant positive association, an adjusted odds ratio of 1.76 (95% CI 1.28-2.42) for the group with nitrate levels between 0.19 and 0.45 mg/L and an adjusted odds ratio of 1.96 (95% CI 1.41-2.72) for the group with nitrate levels of 0.48 mg/L or higher (Chiu, Tsai, & Yang, 2007). However, there are several limiting factors such as nitrate intake (food and water)

estimations and personal risk factors, such as smoking that need to be considered in future studies (Chiu, Tsai, & Yang, 2007). The risk of bladder cancer and nitrate exposure (food and water exposure) was examined in a prospective cohort study in the Netherlands and no association was found, moreover, the effects of nitrate contaminated water on smokers was also examined and it was found that smoking cigarettes did not change the association between bladder cancer risk and nitrate intake, from either food or water (Zeegers et al., 2006).

Although nitrate levels were not specifically measured, a prospective cohort study in China examining the association between colon cancer, rectal cancer, and colorectal cancer incidence and drinking water source (well water) found an increased risk (relative risk) for well water (colon cancer 1.741, 95% CI 1.001-3.029, rectal cancer 2.228, 95% CI 1.432-3.466, colorectal cancer 2.022, 95% CI 1.432-2.854) (Chen et al., 2005). The authors noted that the area studied is an agricultural district and contamination from chemical fertilizer and pesticide use may remain in high concentrations (Chen et al., 2005). Alternatively, no association of colon cancer mortality and municipal nitrate exposure (mean nitrate level of 0.43 mg/L) was found in a matched case control study in Taiwan (Yang, Wu, & Chang, 2007). Interestingly, a case control study in Iowa found negligible associations for colon and rectum cancers with measures of nitrate in public water supplies, but found a positive association with increased colon cancer and nitrate exposure (participants with longer than 10 years average nitrate level of greater than 5 mg/L) among subgroups with low vitamin C intake (odds ratio 2.0, 95% CI 1.2-3.3) and high meat intake (odds ratio 2.2, 95% CI 1.4-3.6) (De Roos et al., 2003).

Possible reproductive and developmental outcomes from maternal exposure of nitrate contaminated drinking water are suggestive at this time. The relationship between methemoglobinemia and abortions was evaluated early on by Schmitz (1961) and showed that higher levels of blood methemoglobinemia were observed in women who threatened to abort or aborted, however; the report indicated that even though nitrates are the most common cause of methemoglobinemia, other causes may have contributed (Schmitz, 1961). More recently, a cluster of spontaneous abortions in LaGrange County Indiana may have been related to elevated levels of nitrate (greater than 19.0 mg/L) in the drinking water (MMWR, 1996). The cases included a 35 year old woman who experienced four consecutive miscarriages in one year and a 37 year old and 20 year old woman who each experienced one miscarriage (MMWR, 1996). Further, the residences of these women were located in proximity to one another and an investigation into the possible sources of nitrate contamination found that contamination from animal wastes, a hog-confinement facility was the likely source of nitrate (MMWR, 1996).

A study of agrichemicals in surface water and birth defects in the United States showed an association between increased risk of birth defects and increased levels of nitrates (and other chemicals) in surface water for the months of increased risk (April-July) (Winchester, Huskins, & Ying, 2009). Another study by Dorsch et al., (1984) found an increased risk of a malformed child among women who consumed groundwater and more importantly, a parallel relationship between increased nitrate concentration and risk for women; a threefold and fourfold increase in risk for women who drank water containing 5-15 parts per million (ppm) of nitrate and greater than 15 ppm (ppm

equivalent to mg/L) (Dorsch et al., 1984). In this study, a seasonal gradient in risk was observed, 0.9 for infants conceived in winter, 3.0 in autumn, 7.0 for spring, and 6.3 for summer (Dorsch et al., 1984). Likewise, a population-based case-control study out of California demonstrated an increased risk for anencephaly in babies whose mothers lived in an area with nitrate in groundwater exceeding the MCL (above 45 mg/L) and an odds ratio of 6.9 was observed in anencephaly risk for maternal exposure and highest nitrate exposure (36-67 mg/L) (Croen, Todoroff, & Shaw, 2001). Moreover, even at lower groundwater nitrate concentrations (5-15 mg/L), an increased risk for anencephaly among groundwater drinkers was observed (odds ratio 2.1, 95% CI 1.1-4.1) (Croen, Todoroff, & Shaw, 2001). In contrast, no increased risks were observed for nitrate exposure, nitrate source, and spina bifida (Croen, Todoroff, & Shaw, 2001). Source of drinking water and central nervous system (CNS) birth defects were examined by Arbuckle et al., (1988) and found a moderate increased risk, though not statistically significant (odds ratio 2.30, 95% CI 0.73-7.29) between nitrate levels of private wells and CNS birth defects. In addition, with public or spring water sources, a negative risk of a CNS birth defect and nitrate levels was observed (Arbuckle et al., 1988).

Well Water Testing

Private well owners are responsible for the testing and maintenance of their private well and private well water supply and the factors surrounding well water testing deserve further examination. The Wisconsin Department of Natural Resources (WI DNR) recommends testing private well water for bacterial contaminants annually

and at least once for nitrate; however, if the location of the private well is within ¼ mile of a crop field, testing should be done annually (Tests for Drinking Water from Private Wells, WI DNR, 2007). Additionally, the DNR recommends that newly constructed wells or wells with no testing history be tested twice for nitrate, six months apart (Tests for Drinking Water from Private Wells, WI DNR, 2007). Further, wells used by pregnant women or infants should be tested at the time of pregnancy and before birth and wells with nitrate testing results close to 10 mg/L should be tested annually (Tests for Drinking Water from Private Wells, WI DNR, 2007).

Two studies in Canada investigated the factors surrounding well water testing. One study reported that 21 percent of surveyed households tested their private water supply (Jones et al., 2006). The main reasons or barriers to more frequent testing included, inconvenience and time issues, no health problems or noticeable water changes, and forgetfulness or procrastination, while cost and lack of information on testing were reasons also noted (Jones et al., 2006). Based on the study by Jones et al., another Canadian study removed the barriers of inconvenience and cost and found that lack of time was the main barrier to private water testing (Hexemer et al., 2008) suggesting that time issues continue to be a factor impeding well water testing practices. Taking access to health services into account and convenience issues, the same study delivered well water testing kits to residents and picked up the samples and found participation for nitrate testing increased from the pilot study at 40.8 percent to the primary study at 47.4 percent (Hexemer et al., 2008); however, even with delivery and pick-up services available for testing convenience, participation was still low as noted by the authors.

The reasons for testing reflect public knowledge and awareness and in addition to addressing the barriers to testing, can provide support for continued or increased educational efforts. A Wisconsin study examining public perceptions to elevated nitrate in drinking water surveyed high-exposure (greater than 12.9 mg/L nitrate) and low-exposure (non-detectable to 2.0 mg/L nitrate) groups among those previously tested and found that approximately 1/3 of respondents regardless of group tested their well water for nitrate because of three main reasons, routine or annual test, new baby, and someone else tested (Schubert et al., 1999). Other reasons included new well installation, real estate transaction, change in water quality, and licensing of a day care facility or organic farm (Schubert et al., 1999). Alarming, 34.5 percent of respondents with nitrate levels above 12.9 mg/L believed their test result was below the health advisory (14.7 percent) or were unsure of results (19.8 percent) (Schubert et al., 1999). Similarly, another study found that among well owners with nitrate levels above 10 mg/L, 31 percent were unaware of the contamination and took no actions (Lewandowski et al., 2008). This suggests that education following nitrate testing is critical.

Prevention and Control

Controlling nitrate contamination, particularly groundwater contamination requires the prevention of nitrate contamination through agricultural management and private homeowner practices and largely involves recognizing the many social, economic, and technical factors involved (Bundy et al., 2005). The role of nitrate

fertilizers in the production of crops is essential; however, the over application of fertilizers is a common problem. To address non-point sources of nitrate contamination (e.g., agricultural crops), several policies are suggested (Daberkow et al., 2001):

- educate producers on best management practices and encourage adoption
- economic incentives (e.g., fertilizer tax)
- regulations on nitrate specific practices

Best management practices for agriculture are suggested for more efficient uptake of nitrate and minimal nitrate leaching into groundwater. Powlson et al., (2008) suggest an integrated systems management approach, where the amount and timing of nitrate fertilizer application is matched to the actual crop nitrate demand, thus decreasing nitrate loss without decreasing crop yield. This kind of integrated approach combined with education and nitrate regulation was implemented in the Central Platte region of Nebraska, a region identified by the Central Platte Natural Resources District (CPNRD) as being a highly cultivated area with average nitrate groundwater levels above the EPA standard (Daberkow et al., 2001). An analysis of this program over a ten year period showed groundwater nitrate levels decrease slightly, 18.9 mg/L (average level during 1989-1993) to 18.1 mg/L (average level during 1994-1998) and CPNRD documented that excess nitrate was related to optimistic yield goals, high levels in irrigated water use, and lack of adherence to fertilizer application guidelines, though the authors stated that the CPNRD program appears to have slowed the trend in nitrate groundwater levels (Daberkow et al., 2001).

Further, nitrate contamination has a significant economic impact. Nitrate

contamination can be also be measured as the cost of treatment and remediation methods, and private well owners with nitrate contaminated wells can pay on average \$200.00 annually for bottled water and \$700.00-\$8,000 average for nitrate removal systems (i.e., reverse osmosis) or a new well (Schubert et al., 1999). In a four-region survey of the United States respondents were asked to consider a hypothetical situation in which their tap water contained nitrates at a level above 50 percent of the EPA standard (Crutchfield & Cooper, 1997). The results showed that on average people were willing to pay between \$45.00 and \$60.00 per household per month for a water filter to reduce nitrates to a safe level, indicating the possible value of risk reduction methods among consumers (Crutchfield & Cooper, 1997). Preventive actions start with the private well owner and proper knowledge about well water construction and management are critical in protecting and ensuring well water quality and safety. Simpson suggests that private well owners should be aware of the following information to ensure the safety and stability of their private well (Simpson, 2004):

- well types
- potential sources of contaminants
- groundwater contaminants and the potential risks to human health
- benefits of properly maintained wells
- importance of a well water testing program

In rural areas, especially in agricultural areas, extra efforts need to be made by health professionals to inform private well owners or those at high risk for possible negative

health effects of nitrate groundwater contamination, specifically households with infants and expectant mothers or women of childbearing age that live on or near farms (WHO, 2007 & Schubert et al., 1999).

CHAPTER THREE

METHODOLOGY

Introduction

The purpose of this descriptive study was to assess and compile information knowledge, awareness, and practices related to nitrate well water testing among private well owners in La Crosse County, specifically, focusing on how private well owners become aware of nitrate well water testing and what prompts or impedes them in testing their well water. In addition, information was sought from the participants about the importance of nitrate well water testing, use of different sources of information, and concern and source of nitrate well water contamination in La Crosse County.

Study Participants

Participants for the study were randomly selected using the Tax Parcel Database and Well Permit Program through the La Crosse County Health Department. This selection process was preferred in order to reach residents who had not tested for nitrate in contrast to those who had tested for nitrate based primarily on laboratory records. A list of La Crosse County residents was compiled using the Tax Parcel Database and to

ensure that the residents owned a well, the list was cross referenced with the Well Permit Program. Adults over the age of 18 who were the homeowner were asked to complete the survey. Survey participation was voluntary and all responses remained confidential. Based on around 4,000 private wells, a random sample size of 351 was sought.

Instrumentation

The survey was designed to gather information on the following categories:

- Demographics and Well Water Characteristics
- Knowledge and awareness about nitrate well water testing
- Barriers to nitrate well water testing
- Concern about nitrate contaminated groundwater

The survey instrument was designed in the following manner to assure its validity and readability. The items in the survey instrument were aligned with the research questions (Appendix B). To determine content validity a panel of experts was selected to review the survey questions. Pilot testing was conducted to assure readability and Outagamie County Wisconsin was chosen because of its similarity in size and agriculture to La Crosse County Wisconsin (J. Steinhoff, personal communication, December 17, 2009).

Validity

Validity was determined through a content validation process with a panel of experts in the state of Wisconsin (Appendix C). The panel included experts in various

fields related to nitrate well water testing and each expert content validation jury member was asked to rate the survey questions based upon the degree in which the statement would reveal a respondent's knowledge, awareness, and practices related to nitrate well water testing. The content validation results were used to improve the survey instrument questions before the pilot testing process.

Readability

The pilot study participants were randomly selected from Outagamie County, Wisconsin by a Drinking Water and Groundwater Specialist at the Wisconsin Department of Natural Resources. They were chosen at random using the tax listing website and cross referenced to make sure the address was serviced by a private well. Each pilot study participant was mailed a cover letter and directions for the survey. The twenty-one question survey was followed by three questions addressing the degree of clarity about the purpose and questions of the survey. The final question addressed whether additional information about nitrate well water testing would be valuable.

Procedures

The survey was mailed to 500 randomly selected participants in La Crosse County from a population of La Crosse County residents. Postal mail addresses were used in contrast to email because the Tax Parcel Database and Well Permit Program do not contain email information. Included with the survey was a cover letter (Appendix D) explaining the purpose of the survey, voluntary participation, and a statement of confidentiality. In addition, completing and returning the survey was stated as consent in

the cover letter. A pre-paid envelope was provided for survey return.

Statistical Analysis

The descriptive data was analyzed by descriptive statistical methods using SPSS software and the mean, percentages, range, and standard deviation were reported. For nominal level data chi-square analysis was used for significance testing between awareness and having tested for nitrate, awareness and age, awareness and importance of testing, and awareness and concern about nitrate groundwater contamination.

CHAPTER FOUR

RESULTS

Introduction

The survey used in this study went through content validation and pilot study processes and the results are detailed below. In each instance, the results aided in improving the survey instrument. A total of 165 surveys (out of 500) from La Crosse County were returned and the results are described below.

Content Validation

The panel included five experts in various fields related to nitrate well water testing and each expert content validation jury member was asked to rate the survey questions based upon the degree in which the statement would reveal a respondent's knowledge, awareness, and practices related to nitrate well water testing. The rating results were summarized (Appendix E) and every survey item had an average rating of 3 or above, meaning that the item is acceptable and has value as a statement for revealing the respondent's knowledge, awareness, and practices related to nitrate well water testing. The content validation jury provided valuable suggestions regarding the stem and responses that was used to improve the survey items. For example, additional response

options for several questions were adopted to provide more specific responses and a ranking system for two survey items was suggested to improve respondent usability and data analysis. In addition, an important follow-up question that asked the respondents the last time their well water was tested for nitrate was suggested and added to the survey instrument.

Pilot Study

Nine participants from Outagamie County were involved in the pilot study process. The twenty-one question survey was followed by three questions addressing the degree of clarity about the purpose and questions of the survey. The final question addressed whether additional information about nitrate well water testing would be useful. Regarding the clarity of the survey purpose and survey questions, the average ratings from the pilot study survey assessment was a 3.4 and 3.8 (Ratings 1 not clear at all, 2 parts were unclear, 3 somewhat clear, 4 clear, 5 very clear) with a range of ratings from 2 to 5. The majority of pilot study participants (6 out of 9) stated that additional information about nitrate well water testing would be valuable to them, indicating the level of possible interest in well water safety. The results from the pilot study revealed that overall the survey was clear and readable.

Survey Results

A total of 500 surveys were mailed to randomly selected private well owners in La Crosse County and 165 were returned resulting in a 33.0 percent return rate. The demographic results are summarized in Table 1. Over fifty percent of the homeowners

that filled out the survey were in two age categories, 40-49 years (28.5 percent) and 50-59 years (30.9 percent) followed by 60-75 years (20.6 percent), 30-39 years (15.8 percent), 18-20 years (3.6 percent), and 76 years or older (0.6 percent). The mean age of the family members in the household was 36 years old with a range of 3 months old to 80 years old. Almost 80 percent of the homeowners live on non-agricultural or farm land, either the countryside, village, or town. The average number of years in current home was 11.29 years with a range of 0 to 49 years. The average age of the well was 11.03 years with a range of 3 months to 88 years and the average depth of the well was 143.90 feet with a range of 24 feet to 600 feet. The primary drinking water source among the survey respondents was regular tap water (78.2 percent) followed by other (i.e., filtered tap water, reverse osmosis) (13.3 percent), and bottled water (8.5 percent).

Table 1. Summary: Demographic Information

Demographic	Category	Percent of survey population, Mean, Range
Age of homeowner filling out the survey	18-20 years	3.6 percent
	30-39 years	15.8 percent
	40-49 years	28.5 percent
	50-59 years	30.9 percent
	60-75 years	20.6 percent
	76 or older	0.6 percent
Location of home	Agricultural or farmland	21.0 percent
	Countryside, village, town (non-agricultural)	79.0 percent
Number of years in current home	No categories	Mean 11.29 years
		Range 0-49 years
		Std. Deviation 9.5
Age of well (years)	No categories	Mean 11.03 years
		Range .33-88 years
		Std. Deviation 10.7
Depth of well (feet)	No categories	Mean 143.9 feet
		Range 24-600 feet
		Std. Deviation 124.5
Primary drinking water source	Regular Tap Water	78.2 percent
	Other (Filtered Tap Water, Reverse Osmosis)	13.3 percent
	Bottled Water	8.5 percent

Approximately 85 percent of the survey respondents were aware that they could have their well water tested for nitrates, while 15.2 percent were not aware. Among those that were aware of nitrate well water testing, 28.5 percent learned about nitrate well water testing from the La Crosse County Health Department, 19.0 percent learned as a result of a real estate transaction, 18.4 percent learned from an “other” source (i.e., well driller, employment, plumber, own knowledge), 18.4 percent learned from the media, 8.9 percent learned from a neighbor, and 6.7 percent learned from a doctor or health care provider (Figure 1).

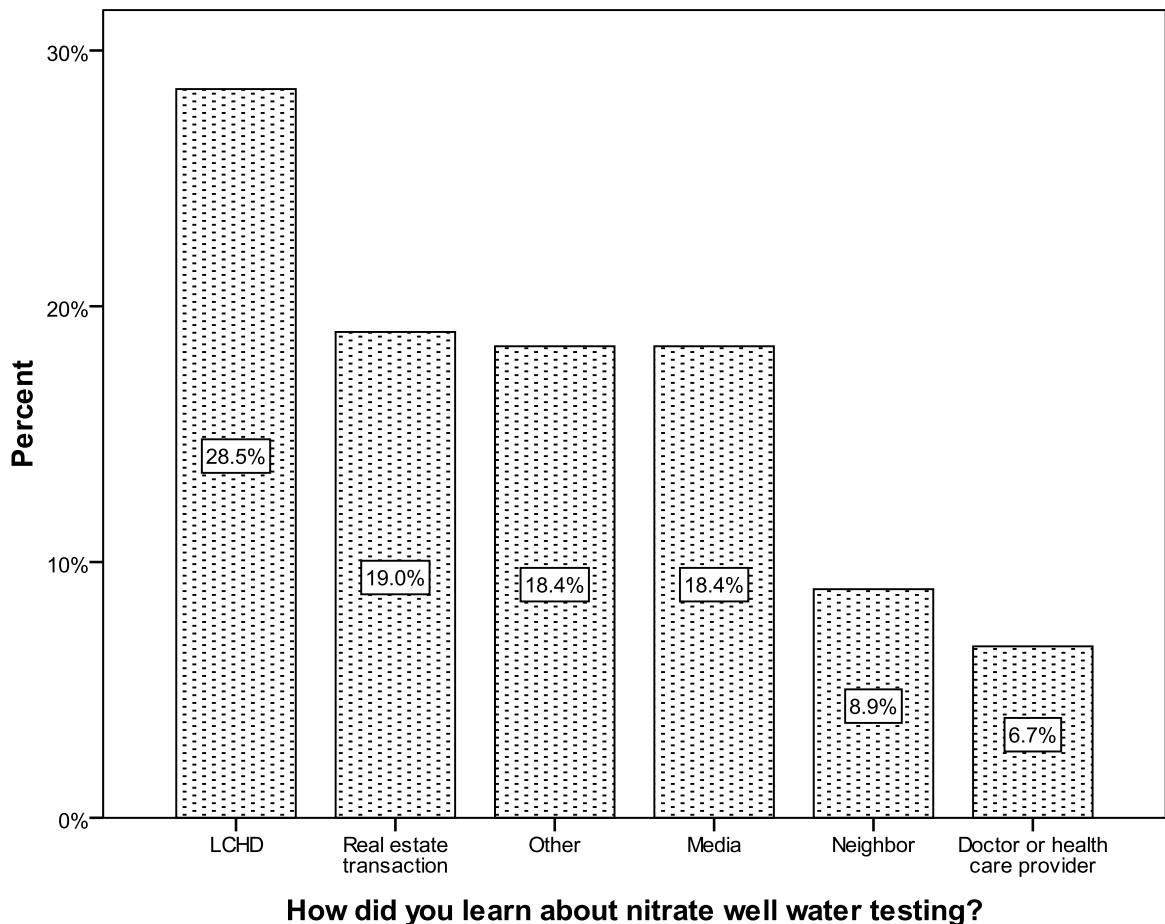


Figure 1. How survey respondents learned about nitrate well water testing

Over 90 percent of the survey respondents felt that nitrate well water testing was “somewhat” important (49.4 percent) or “very” important (44.5 percent), while 6.1 percent felt that nitrate well water testing was “not at all” important. Among those that responded “somewhat important” or “very important” 78.3 percent indicated that the most important reason to test their private well water was for water quality and safety, followed by 15.8 percent for the health of infants living in household, 3.3 percent for pregnant women or women of childbearing age, and 1.3 percent for routine well maintenance and “other” (Figure 2).

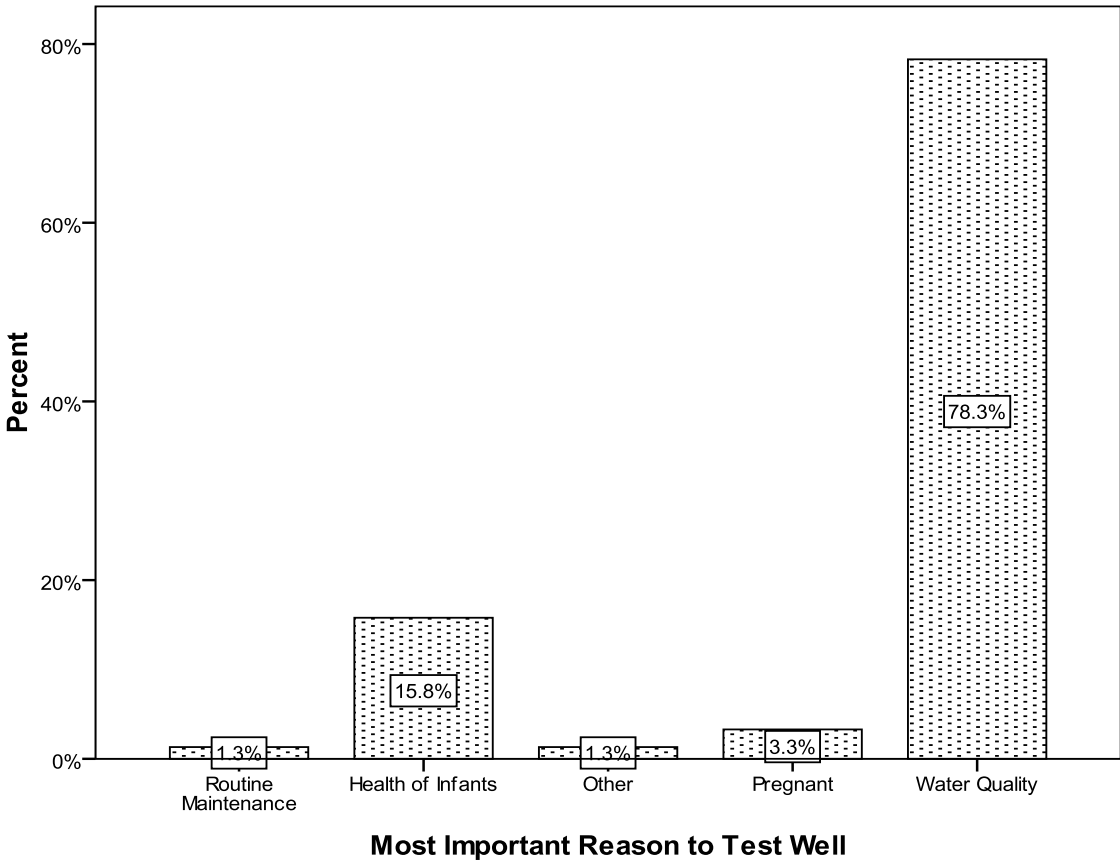


Figure 2. Most important reasons to test well water for nitrate among survey respondents

Regarding the importance of nitrate well water testing, among those that responded “not at all important” (9 respondents) 44.4 percent indicated “other” reasons why nitrate well water testing was not important and the “other” reasons included, were unaware of testing, laziness, no children in house, and lack of information about testing. Further reasons indicated why nitrate well water testing is not important included, nitrate is not a health issue (22.2 percent), nitrate does not affect water quality (22.2 percent), and testing for nitrate is not necessary (11.1 percent).

Respondents were asked if in the past they had a question about their private well, how information was obtained and 35.0 percent of the survey respondents contacted their well driller or pump installer, 32.0 percent indicated they have never had a question about their private well, 15.5 percent called the local health department, 10.2 percent obtained a copy of their well construction report, 3.9 percent indicated an “other” source (i.e., DNR, laboratory, plumber, friend, internet), and 3.4 percent obtained information from their real estate agent or seller of home (Figure 3).

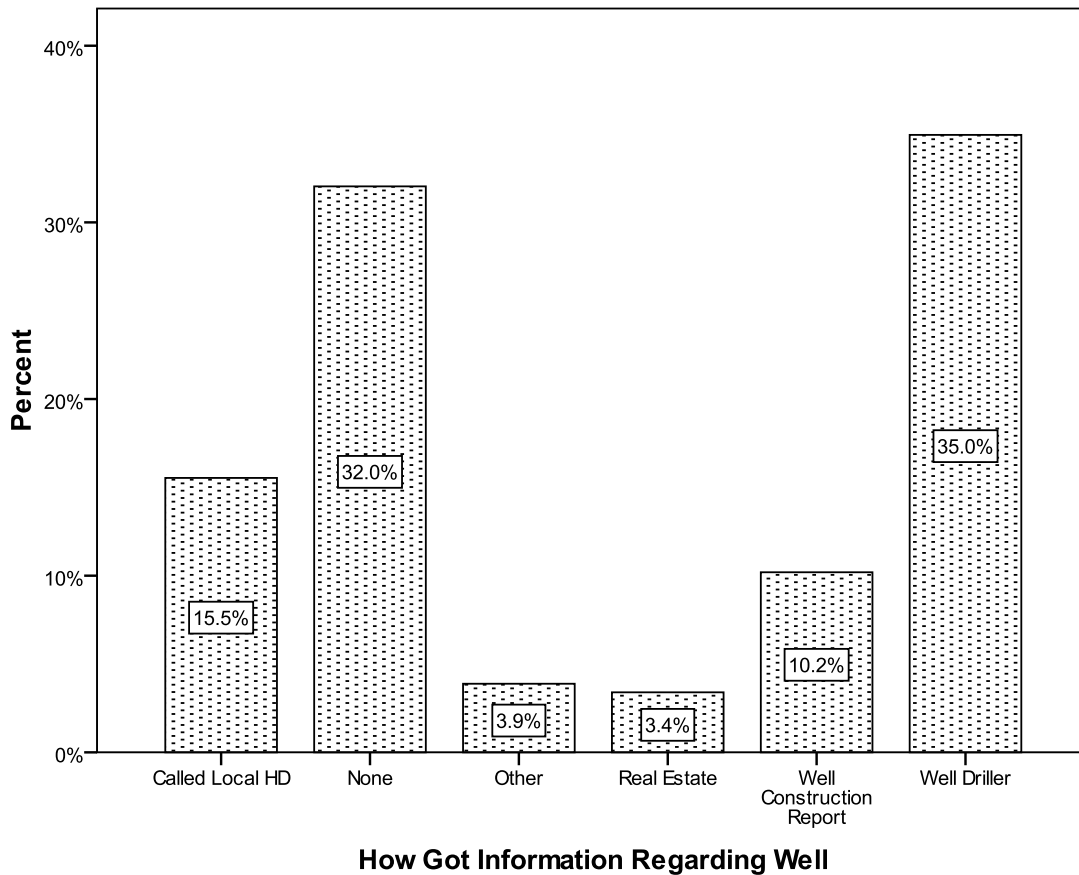


Figure 3. How survey respondents got information about their private well

Regarding sources of information about private wells and well water testing, respondents were asked to rank various sources of information and the frequencies for the top three ratings are listed in Table 2 (a & b) below. The resulting rankings are summarized in Table 3 below. Rankings were designated as 1 indicating most likely through 6 indicating least likely. The results indicate for information about the well, the number one ranked source is the La Crosse County Health Department website, followed

by the Wisconsin Department of Natural Resources website, and third ranked, a mailed flyer or brochure. For information about well water testing, the number one ranked source is the La Crosse County website, followed by a mailed flyer or brochure, and third ranked, the Wisconsin Department of Natural Resources website.

Table 2 (a). Frequency of top three rankings (number of times ranked as number 1, 2, and 3) to obtain information about well

Source (n=120)	Frequency ranked as number 1	Frequency ranked as number 2	Frequency ranked as number 3
La Crosse County Health Department Website	60	26	4
Wisconsin Department of Natural Resources Website	18	56	11
Mailed flyer or brochure	29	11	48
Newspaper	5	9	22
Television	6	10	21
Radio	2	8	14

Table 2 (b). Frequency of top three rankings (number of times ranked as number 1, 2, and 3) to obtain information about well water testing

Source (n=117)	Frequency ranked as number 1	Frequency ranked as number 2	Frequency ranked as number 3
La Crosse County Health Department Website	60	23	7
Wisconsin Department of Natural Resources Website	14	51	10
Mailed flyer or brochure	34	14	38
Newspaper	5	11	25
Television	2	12	17
Radio	2	6	20

Table 3. Summary: Ranking of use of sources

Sources	Ranking-To obtain information about well	Ranking-To obtain information about well water testing
La Crosse County Health Department Website	1	1
Wisconsin Department of Natural Resources Website	2	3
Mailed flyer or brochure	3	2
Newspaper	4	4
Television	5	5
Radio	6	6

Among the survey respondents, 61.3 percent have tested their well water for nitrate, while 38.7 percent of the respondents have not tested. Of the 61.3 percent that have tested their well water for nitrate, 29.5 percent had their well 3-5 years ago, 23.2 percent had their well tested 1-2 years ago, 18.9 percent had their well tested less than 1 year ago, 18.9 percent had their well tested 6-10 years ago, and 9.5 percent had their well tested greater than 10 years ago (Figure 4).

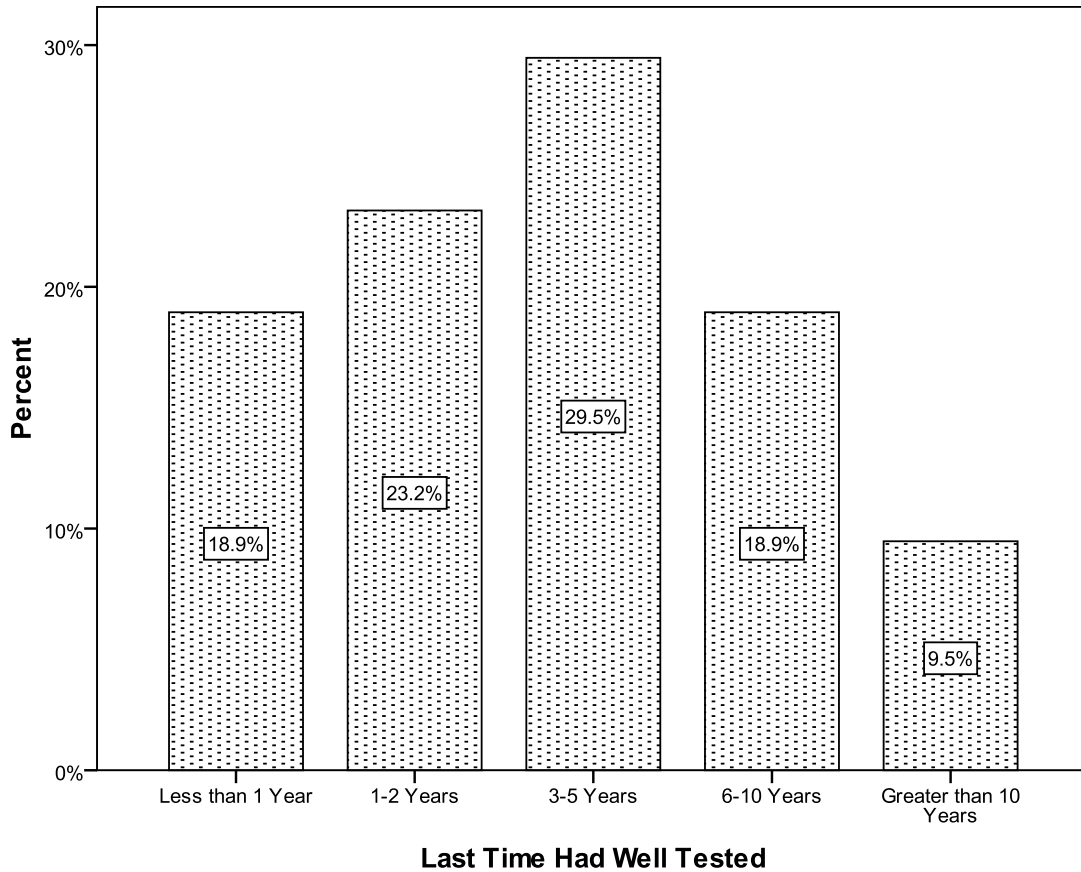


Figure 4. Last time well water was tested for nitrate

Respondents were asked what prompted them to test their well water for nitrate and the results are summarized in Table 4 below with 23.58 percent indicating the La Crosse County Health Department, 17.92 percent indicating a new well or well maintenance, and 12.26 percent indicating the purchase or selling of a home as the top three reasons that prompted respondents to test their well water for nitrate.

Table 4. Summary: What prompted testing well water for nitrate
(Among those that have tested their well water for nitrate)

Category	Percent of Survey Respondents
La Crosse County Health Department recommendation	23.58 %
New well or well maintenance	17.92%
Purchased or sold home	12.26%
Changes in water	7.55%
Curiosity	7.55%
Other	7.55%
Infants in household	6.6%
Yearly test	4.72%
Doctor or health care provider recommendation	4.72%
Neighbor's test result	3.77%
Built home	3.77%

Among those that have not tested their well water for nitrate, the reasons for not testing are summarized below in Table 5. The top three reasons were no health problems or noticeable changes in water (40.8 percent), lack of information about testing (19.4 percent), and were not aware of nitrate well water testing (15.3 percent).

Table 5. Summary: Reasons for not testing for nitrate
(Among those that have not tested their well for nitrate)

Category	Percent of Survey Respondents
No health problems or noticeable changes in water	40.8 %
Lack of information about testing	19.4 %
Were not aware of nitrate well water testing	15.3 %
Cost	11.2%
Inconvenience	9.2 %
Other (were not aware of health issues, new well)	4.1 %

Regarding the degree to which survey respondents are concerned about nitrate well water contamination in La Crosse County, 60.3 percent were “somewhat” concerned, 26.5 percent were “not” concerned, and 13.2 percent were “very” concerned. Respondents were asked in their opinion, the greatest source of nitrate groundwater contamination in La Crosse County. The results are summarized in Table 6 below with 54.2 percent of the respondents indicating the use of agricultural fertilizers.

Table 6. Summary: Greatest Source of Contamination

Category	Percent of Survey Respondents
Agricultural fertilizer	54.2 %
Fertilizer use for private residences	14.4 %
Application of animal wastes to land (i.e., manure)	10.5 %
Other (i.e., no opinion, not sure)	10.5 %
Application of bio-solids (e.g., land applied sewage, municipal sludge, whey)	4.6 %
Natural atmospheric sources	3.3 %
Septic system leakage	2.6 %

To compare data and test for significance, chi-square testing was conducted. All tests used a significance level of 0.05. Awareness of nitrate well water testing (yes or no) and tested for nitrate (yes or no) was cross tabulated and found to be significant (Asymp. Sig. 2-sided 0.000, Pearson chi-square value 37.73). Among those that were aware of nitrate well water testing, 69 percent had tested their well water for nitrate and 31 percent had *not* tested their well water for nitrate represented in Figure 5 below (Appendix F).

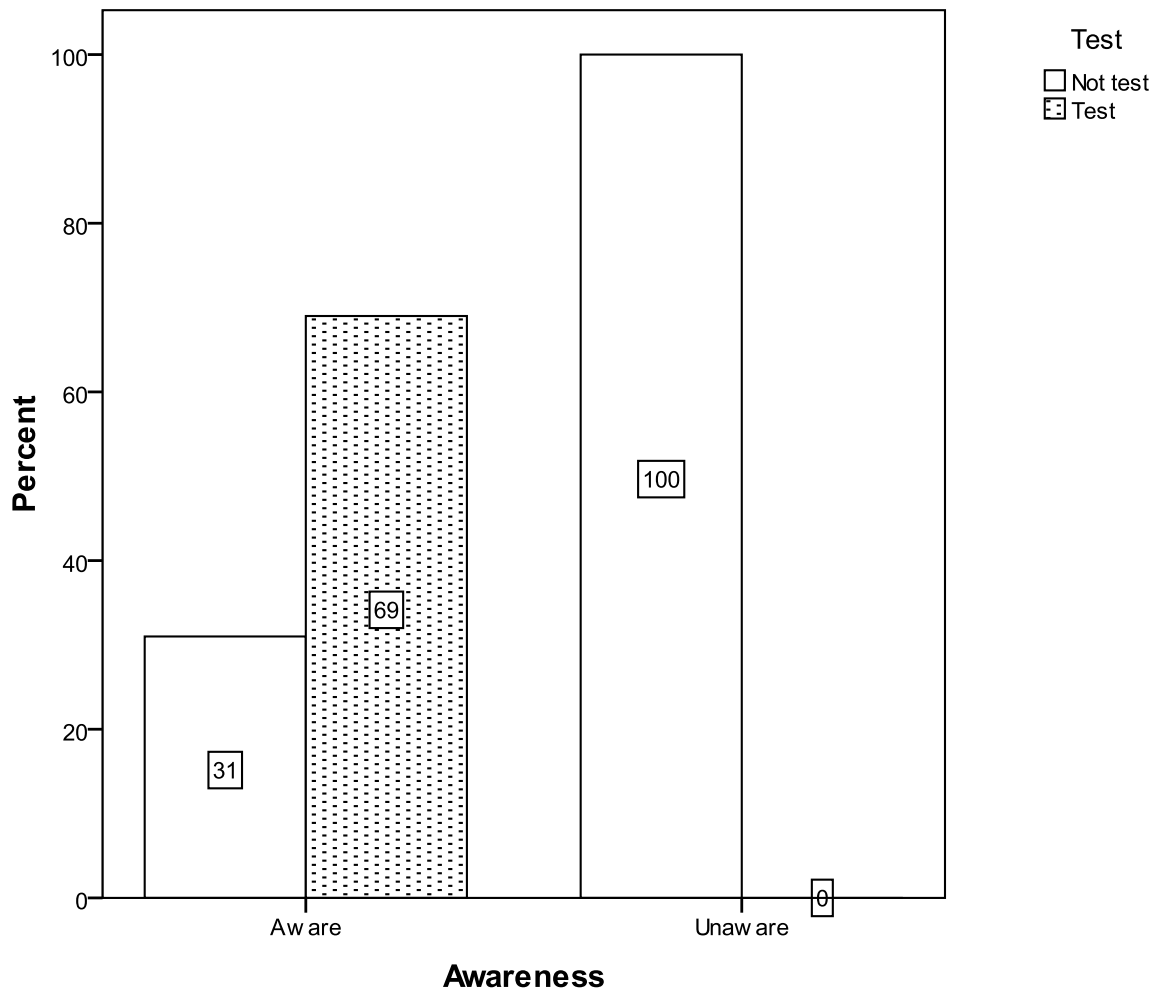


Figure 5. Awareness and Testing

Age group and awareness were compared and no significance was found (Asymp. Sig. 2-sided 0.744), however, among all age groups 13.3 percent were not aware of nitrate well water testing, while 86.7 percent were aware. Awareness and importance of testing for nitrate (Question, how important do you think it is to test your well water for nitrate)

was compared and no significance was found (Exact Sig. 2-sided 0.086), yet regardless of awareness, 6.1 percent felt it was not important to test for nitrate, while 49.4 percent felt it was somewhat important, and 44.5 percent felt it was very important to test their well water for nitrate. Lastly, awareness and degree of concern about nitrate groundwater contamination was compared and no significance was found (Exact Sig. 2-sided 0.564), yet regardless of awareness, 55.3 percent felt somewhat concerned followed by 31.1 percent not concerned and 13.7 percent very concerned about nitrate groundwater contamination in La Crosse County.

CHAPTER FIVE

Summary

The purpose of this study was to assess knowledge, awareness, and practices related to nitrate well water testing among private well owners in La Crosse County. The results of the survey are aligned with the research questions. Recognizing what prompts and impedes private well owners are important considerations in identifying how to better reach and educate the public about nitrate well water testing. Although efforts are needed to reduce the amount of nitrogen input into groundwater in Wisconsin, directed educational efforts based on local data may be the best method for informing the public about nitrate contaminated groundwater and reducing exposure. Effective water contamination management programs should incorporate information about public awareness to better formulate educational programs and influence policy efforts.

Conclusions

Based on the results, private well owners become aware of nitrate well water testing from four main sources, the La Crosse County Health Department (28.5 %), a real estate transaction (19.0%), other (e.g., well driller, employment, plumber, own knowledge) (18.4%), and the media (18.4%). This suggests that through the activities and services at the La Crosse County Health Department, private well owners are learning

about nitrate well water testing. Surprisingly, only 6.7 percent learned about nitrate well water testing from a doctor or health care provider highlighting a potential area for improvement. Additionally, among those that were aware of nitrate well water 31.0 percent had *not* tested their well water indicating a gap in being aware and the action of testing. Possible barriers identified from the survey were no health problems or noticeable changes in water (40.8%), lack of information about testing (19.4%), lack of awareness about nitrate well water testing (15.3%), cost (11.2%), inconvenience (9.2%) and other (4.1%). These barriers to testing are similar to those noted in previous studies (Jones et al., 2006 & Hexamer et al., 2008). The problem with not recognizing any health problems or changes in the water is that nitrate is an odorless, colorless, and tasteless chemical that can not be visually identified and although the health issues about nitrate are primarily concerned with infant health, the effects of long term nitrate exposure from contaminated drinking water are unknown as well as the possible synergistic effects of nitrate with other contaminants (Kite-Powell & Harding, 2006), thus, preventive actions by means of nitrate well water testing are practical. Lack of information about nitrate well water testing implies that there is potential for education or informative methods that would assist private well owners with testing their water, such as information about where to have a nitrate test done and how to collect a water sample.

It appears that among the survey respondents, a little over half (54.2%) understand that the use of agricultural fertilizers is the greatest source of nitrate

groundwater contamination. An understanding of groundwater contamination promotes a greater recognition of the activities, both of private residents and agricultural producers, which contribute to groundwater contamination and thus, the opportunity for practices that affect groundwater quality and minimize contamination can be applied.

The three most common sources of information for private well owners with questions about their private well were the well driller or pump installer (35.0%), contacting the local health department (15.5%), and obtaining a well construction report (10.2%). Surprisingly, 32.0% of the survey respondents have never had a question about their private well and thus never sought out any sources for information. To determine what sources of information private well owners would likely use to obtain information about their well and well water testing, in both instances, the La Crosse County Health Department website was the top choice. Regarding information about their well, the Wisconsin Department of Natural Resources website was the second highest choice, followed by a mailed flyer or brochure. In contrast, regarding information about well water testing, the second highest choice was a mailed flyer or brochure, followed by the Wisconsin Department of Natural Resources website. In both instances, the newspaper, television, and radio ranked as unlikely sources for information, suggesting that among the survey respondents, the preferred choice for information about wells and well water testing is the La Crosse County Health Department and Department of Natural Resources websites, however, a mailed flyer or brochure could also serve as an accepted source of information. Further, a mailed flyer or brochure that included directions to the information about well water testing on La Crosse County Health Department website

may be valuable to private well owners.

An example of the use of a website for private well owners about well water testing information is from Portage County Wisconsin. In Portage County, 20 percent of wells tested exceeded the nitrate standard and Portage County has developed a comprehensive groundwater program through the work of the Portage County Groundwater Citizens Advisory Committee (Portage County Groundwater website, n.d., 2005). Most impressive is the website with information broken into four categories, Understanding Groundwater, Teaching and Learning, Managing the Resource, and Taking Action. Included is an extensive resource of information related to nitrate, such as testing information, reactive and preventive measures, sources of contamination, health information, well management, and a variety of links to other agencies. Additionally, the Portage County Groundwater website offers information about groundwater laws and regulation, management plans, and youth educational resources. Based on the results of the study, survey respondents indicated that the La Crosse County Health Department and Department of Natural Resources websites are likely sources of information; therefore, websites for local information should provide a comprehensive explanation of information related to nitrate well water testing relevant to La Crosse County.

The prompting source among those that have tested their well water for nitrate, was, the La Crosse County Health Department (23.58%), the installation of a new well or well maintenance (17.92%), and the purchase or selling of a home (12.26%). Among the

survey respondents, 49.4 percent and 44.5 percent believe that it is “somewhat” or “very” important to test their private well water for nitrate and the majority believe the most important reason is for water quality and safety (78.3%), though the use of the word, “safety” in the question response may have been misinterpreted or seen as a “catch all” word for overall health; however, 15.8 percent believe the most important reason is for the health of infants. Nitrate well water testing for infant health is the message that should be emphasized and communicated, especially to expectant mothers living on farms or near farm land. A total of 73.5 percent of survey respondents are “somewhat” or “very” concerned about nitrate well water contamination in La Crosse County, however, 26.5 percent are “not” concerned suggesting that private well owners recognize or have interest in nitrate groundwater contamination.

Recommendations

Awareness and education are important considerations in the development of a well water testing program and the degree to which the public can understand the importance and need to practice regular well water testing will depend on how the information is delivered (Simpson, 2004). The results from this survey may assist local health agencies in the development of an educational program aimed at increasing knowledge and awareness about nitrate well water testing and reducing exposure through nitrate testing practices.

Collaboration on educational and informative efforts about nitrate well water testing between the local health department and other agencies may aid in the delivery of

the message to the public. A program should consider how to capture the attention of the public and a series of short educational messages over a period of time may be the best approach (as cited in Simpson, 2004). This is considered the preparation stage or initial awareness building stage (as cited in Simpson, 2004) and based on the survey results messages about the sources of groundwater contamination, the importance of testing, and the potential health effects of nitrate contamination should be communicated. In this instance, a mailed flyer or brochure may be considered to initially introduce and inform the public about nitrate well water testing. To further engage the public and encourage participation in well water testing, the second stage, or illumination stage focuses on awareness and education (as cited in Simpson, 2004). This should involve education about where to test and how to collect a sample for testing. More importantly, information about how to interpret test results and what remedial actions can be taken are critical aspects towards reducing exposure. Additionally, information about the necessity of regular testing should be communicated to encourage testing and aid private well owners in establishing annual testing practices. For example, private well owners should be aware that if their well is located within $\frac{1}{4}$ mile of crops or if test results are close to 10 mg/L, annual testing is recommended. Moreover, groundwater movement is subject to change, thus nitrate contamination may change over time highlighting the importance of annual testing.

Because the cost of testing on an annual basis may be prohibitive for some, the local health department may consider a coupon or discount for those testing for the first time or additional ways that the cost may be offset to encourage nitrate well water testing.

In addition, improving access to nitrate testing information and testing kit materials should be considered and public locations, such as public libraries, may be a useful location. The final stage, education and empowerment involves the active participation in groundwater protection efforts (as cited in Simpson, 2004). This can be carried out by the regular practice of nitrate well water testing. Further, education about methods to protect ones private water supply should be continued, which includes well maintenance information. It should be made clear to private well owners that the data collected from regular well water testing is important information that assists local and state agencies in identifying the extent of the problem and areas of concern and can more importantly, alert those agencies to the need for additional monitoring or regulatory or policy efforts (Mechenich, Leatherman, & Masarik, 2004). In this instance, communication and cooperation between the health educator and other professional health agencies would be necessary in order to develop and promote collaborative efforts with mutual interest that are aligned with protecting the health of the public.

As previously mentioned, only 6.7 percent learned about nitrate well water testing from a doctor or health care provider. This is an important area to improve as infants and expectant women and women of childbearing age are the primary risks groups. Local health departments should consider providing information to doctors or health care providers to include in prenatal visits and prenatal health materials. Further, the local health department should consider conducting a seminar about nitrate and nitrate well water testing for local health care professionals. Local health agencies should consider targeted educational efforts towards the primary risk groups. For example, a health

educator could present information about nitrate, its associated health effects, and nitrate well water testing at prenatal classes. In addition, subsequent presentations at prenatal classes would provide an opportunity for testing; giving expectant parents the option of bringing in a water sample for the health educator to take to the health department for nitrate testing.

In order to decrease nitrate contamination in the environment, policy or regulatory actions should be considered by the local County Board or appropriate regulatory agencies. In addition, efforts towards the monitoring and collection of nitrate data should be supported. Furthermore, research into the sources of nitrate groundwater contamination and changes in groundwater movement may be useful in determining the extent of the problem and appropriate remediation actions. However, it should be noted, that higher levels of nitrate could be due to the availability of a laboratory for testing. Future survey studies about knowledge, awareness, and practices related to nitrate well water testing should consider the diversity of the jury members involved in the review of the survey instrument.

Overall, based on the results of this survey, it is apparent that there is a need for educational efforts to inform the public about nitrate well water testing. The health effects associated with nitrate well water testing support a preventive approach to protecting health, especially to high risk groups such as infants, pregnant women or women of childbearing age and those groups located on or near farm land. Although the respondents of the survey are largely aware of nitrate well water testing, there is a gap in testing practices, thus efforts aligned with encouraging and promoting testing and the

establishment of regular testing practices should be a priority. The top barriers to nitrate well water testing mentioned above can provide support for increased educational efforts aligned with increasing awareness about nitrate well water testing. The belief that nitrate will cause noticeable changes to one's health or changes to one's water should be addressed with educational messages about the unseen nature of nitrate in water and relevant information regarding the possible associations of nitrate and other health issues, such as cancer or reproductive and developmental outcomes. Increasing awareness and testing may take time and thus, a program or awareness campaign that is consistent may have a greater effect. Furthermore, consistent and collaborative efforts will help to reinforce the educational and preventive messages offered by the La Crosse County Health Department, real estate agencies, and the general media and assist in the establishment of regular testing practices among private well owners.

REFERENCES

- Arbuckle, T. E., Sherman, G. J., Corey, P. N., Walters, D., & Lo, B. (1988). Water nitrates and cns birth defects: A population-based case-control study. *Archives of Environmental Health*, 43, (2), 162-167.
- Avery, A. A. (1999). Infantile methemoglobinemia: Reexamining the role of drinking water nitrates. *Environmental Health Perspectives*, 107, (7), 583-586.
- Boeing, H., Frentzel-Beyme, R., Berger, M., Berndt, V., Gores, W., Korner, M., Lohmeier, R., Menarcher, A., Mannl, H., Meinhardt, M., Muller, R., Ostermeier, H., Paul, F., Schwemmler, K., Wanger, K. H., & Wahrendorf, J. (1991). Case-control study on stomach cancer in Germany. *International Journal of Cancer*, 47, (6), 858-864.
- Bundy, L. G., Knobeloch, L., Webendorfer, B., Jackson, G. W. & Shaw, B. H. (2005). Nitrates in Wisconsin groundwater: Sources and concerns. University of Wisconsin-Extension (G3054).
- Canter, L. W. (1997). *Nitrates in Groundwater*. CRC Press, Inc. Boca Raton, Florida.
- Centers for Disease Control and Prevention & National Center for Environmental Health. (1998). A Survey of the quality of water drawn from domestic wells in nine Midwest states. Retrieved November 20, 2009 from, <http://www.cdc.gov/nceh/hsb/disaster/pdfs/A%20Survey%20of%20the%20Quality%20of%20Water%20Drawn%20from%20Domestic%20Wells%20in%20Nine%20Midwest%20States.pdf>
- Chen, K., Yu, W., Ma, X., Yao, K., & Jiang, Q. (2005). The association between drinking water source and colorectal cancer incidence in Jiashan County of China: A prospective cohort study. *European Journal of Public Health*, 15, (6), 652-656.
- Chern, L., Kraft, G., & Postle, J. (1999). Nitrate in groundwater-A continuing issue for Wisconsin citizens. Wisconsin Department of Natural Resources. Retrieved November 15, 2009 from <http://dnr.state.wi.us/org/water/dwg/gw/pubs/nitrate.pdf>

- Chiu, H. F., Tsai, S. S., & Yang, C. Y. (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*, 70, 1000-1004.
- Croen, L. A., Todoroff, K., & Shaw, G. M. (2001). Maternal exposure to nitrate from drinking water and diet and risk for neurall tube defects. *American Journal of Epidemiology*, 153, (4), 325-331.
- Crutchfield, S. R. & Cooper, J. (1997). Valuing risk reduction: The example of nitrates in drinking water. *Food Safety*, January-April.
- Daberkow, S., Taylor, H., Gollehon, N., & Moravek, M. (2001). Nutrient management programs, nitrogen fertilizer practices, and groundwater quality in Nebraska's central platte valley (U.S), 1989-1998. *The Scientific World*, 1, (S2), 750-757.
- De Roos, A. J., Ward, M. H., Lynch, C. F., & Cantor, K. P. (2003). Nitrate in public water supplies and the risk of colon and rectum cancers. *Epidemiology*, 14, (6), 640-649.
- Dorsch, M. M., Scragg, R. K., McMicheal, A. J., Baghurst, P. A., & Dyer, K. F. (1984). Congenital malformations and maternal drinking water supply in rural south Australia: A case-control study. *American Journal of Epidemiology*, 119, (4), 473-486.
- Fan, A. M. & Steinberg, V. E. (1996). Health implications of nitrate and nitrite in drinking water: An update on methemoglobinemia occurrence and reproductive and developmental toxicity. *Regulatory Toxicology and Pharmacology*, 23, 35-42.
- Fewtrell, L. (2004). Drinking-water nitrate, methemoglobinemia, and global burden of disease: A discussion. *Environmental Health Perspectives*, 112, (14), 1371-1374.
- Freedman, D. M., Cantor, K. P., Ward, M. H., & Helzlsouer, K. J. (2000). A case-control study of nitrate in drinking water and non-hodgkin's lymphoma in Minnesota. *Archives of Environmental Health*, 55, (5), 326-329.
- Greer, F. R. & Shannon, M. (2010). Infant methemoglobinemia: The role of dietary nitrate in food and water. *Pediatrics*, 116, (3), 784-786.
- Gulis, G., Czompolyova, M., & Cerhan, J. R. (2002). An ecologic study of nitrate in municipal drinking water and cancer incidence in Trnava District, Slovakia. *Environmental Research*, 88, (3), 182-187.

- Hexemer, A. M., Pintar, K., Bird, T. M., Zentner, S. W., Garcia, H. P., & Pollari, F. (2008). An investigation of bacteriological and chemical water quality and the barriers to private well water sampling in a southwestern Ontario community. *Journal of Water and Health, 6*(4), 521-525.
- Huston, S. S., Barber, N. L., Kenny, J. F., Linsey, K. S., Lumia, D. S., & Maupin, M. A. (2004). Estimated use of groundwater in the United States in 2000. United States Geological Survey Circular 1268. Denver, Colorado: U.S. Geological Survey.
- Jones, A. Q., Dewey, C. E., Dore, K., Majowicz, S. E., McEwwn, S. A., Toewes-David, W., Eric, M., Carr, D. J., & Henson, S. J. (2006). Public perceptions of drinking water: A postal survey of residents with private water supplies. *BMC Public Health, 6*, 94-104.
- Kassulke, N., & Chern, L. (2006). Groundwater, Wisconsin's buried treasure. Wisconsin Department of Natural Resources, PUBL-DG-055-06.
- Kite-Powell, A. C., & Harding, A. K. (2006). Nitrate contamination in Oregon well water: Geologic variability and the public's perception. *Journal of the American Water Resources Association, 42*, (4), 975-987.
- Knobeloch, L., Salna, B., Hogan, A., Postle, J., & Anderson, H. (2000). Blue babies and nitrate-contaminated well water. *Environmental Health Perspectives, 108*, (7), 675-678.
- Kross, B. C., Hallberg, G. R., Bruner, R., Cherryholmes, K., & Johnson, K. (1993). The nitrate contamination of private well water in Iowa. *American Journal of Public Health, 83*, (2), 270-272.
- Lewandowski, A. M., Montogonery, B. R., Rosen, C. J., & Moncrief, J. F. (2008). Groundwater nitrate contamination costs: A survey of private well owners. *Journal of Soil and Water Contamination, 63*, (3), 153-161.
- Manassaram, D. M., Backer, L. C., & Moll, D. M. (2006). A review of nitrates in drinking water: Maternal exposure and adverse reproductive and developmental outcomes. *Environmental Health Perspective, 12*, (1), 153-163.
- Mechenich, C., Leatherman, J., & Maskarik, K. (2004). A Guide to organizing a community drinking water testing and educational program. Center for Watershed Science and Education, College of Natural Resources, University of Wisconsin-Stevens Point and University of Wisconsin-Extension, 1-39.

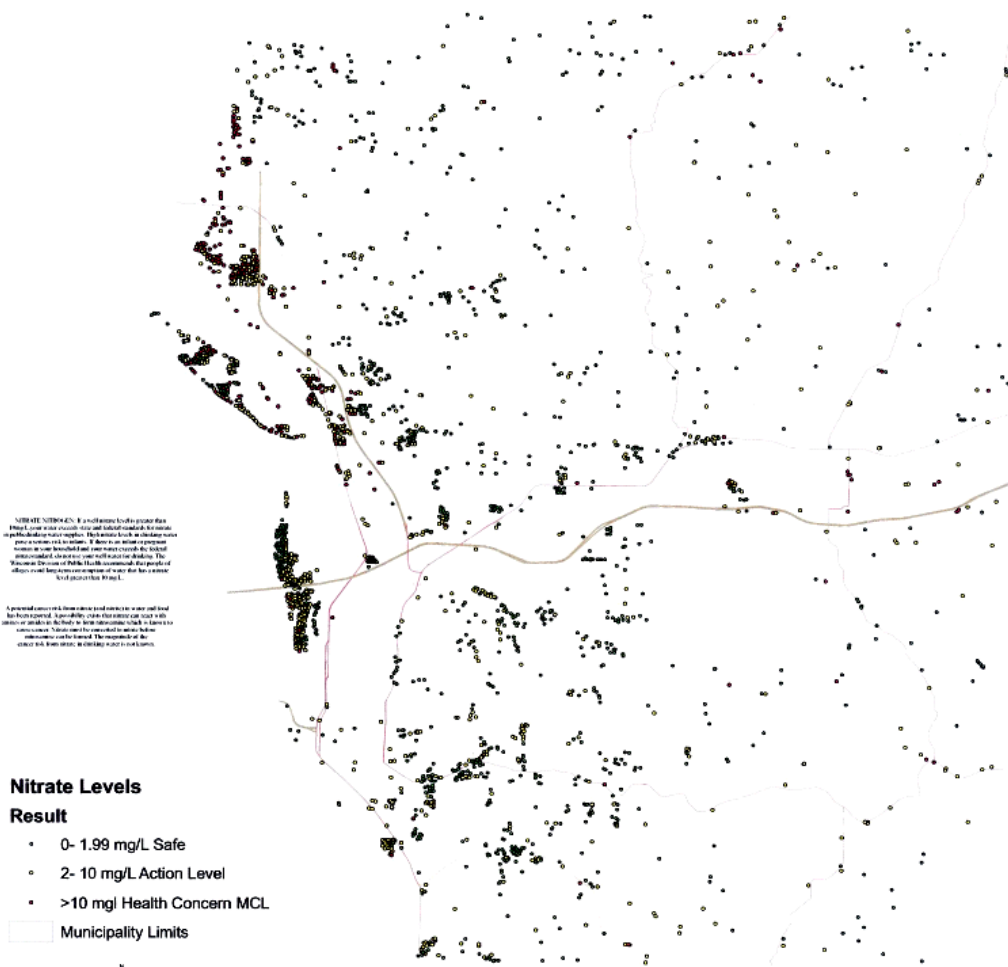
- Morales-Suarez-Varela, M.M., Llopis-Gonzales, A., & Tejerizo-Perez, M.L. (1995). Impact of nitrates in drinking water on cancer mortality in Valencia, Spain. *European Journal of Epidemiology*, 11, 15-21.
- Morbidity and Mortality Weekly. (1996). Spontaneous abortions possibly related to ingestion of nitrate-contaminated well water-La Grange County, Indiana, 1991-1994. Centers for Disease and Control. Retrieved November 18, 2009 from <http://www.cdc.gov/mmwr/preview/mmwrhtml/00042839.htm>
- Morbidity and Mortality Weekly. (1993). Methemoglobinemia in an infant-Wisconsin, 1992, 42, (12), 217-219. Retrieved February 28, 2010 from <http://www.cdc.gov/mmwr/preview/mmwrhtml/00020077.htm>
- Nolan, B. T., Ruddy, B. C., Hitt, K. J., & Helsel, D. R. (1997). Risk of nitrate in groundwaters of the United States-A national perspective. *Environmental Science & Technology*, 31, (8), 2229-2236.
- Nolan, B. T., Ruddy, B. C., Hitt, K. J., & Helsel, D. R. (1998). A national look at nitrate contamination of groundwater. *Water Conditioning and Purification*, 39, (12), 76-79.
- Portage County Groundwater website, Retrieved March 20, 2010 from <http://www.co.portage.wi.us/Groundwater/main/index.htm>.
- Powlson, D. S., Addiscott, T. M., Benjamin, N., Cassman, K. G., Kok, T. M., van Grinsen, H., L'hirondel, J., Avery, A. A., & Kessel, C. (2008). When does nitrate become a risk for humans. *Journal of Environmental Quality*, 37, 291-295.
- Rademacher, J. J., Young, T. B., & Kanarek, M. S. (1992). Gastric cancer mortality and nitrate levels in Wisconsin drinking water. *Archives of Environmental Health*, 47, (4), 292-294.
- Sawvell, D. & laboratory staff. (2010). La Crosse county lab nitrate levels for last 10 years (GIS map). La Crosse County Health Department.
- Sawvell, D. personal communication, March 25, 2010.
- Schmitz, J. T. (1961). Methemoglobinemia-A cause of abortions? *Obstetrics and Gynecology*, 17, (4), 413-415.
- Schottenfeld, D., & Fraumeni, J. F. (2006). *Cancer Epidemiology and Prevention* (3rd ed.). Oxford University Press, Inc: New York, New York.

- Schubert, C., Knobeloch, L., Kanarek, M. S., & Anderson, H. A. (1999). Public response to elevated nitrate in drinking water wells in Wisconsin. *Archives of Environmental Health*, 54, (4), 242-247.
- Shaw, B. (1994). Nitrogen contamination sources: A look at relative contributions. Nitrate in Wisconsin's Groundwater Strategies and Challenges: University of Wisconsin-Steven's Point, Central Wisconsin Groundwater Center.
- Simpson, H. (2004). Promoting the management and protection of private water wells. *Journal of Toxicology and Environmental Health, Part A*, 67, 1679-1704.
- Steinhoff, J. personal communication, December 17, 2009.
- Tests for Drinking Water from Private Wells. Wisconsin Department of Natural Resources. (2007). PLUB-DG-023.
- Ward, M. H., Cerhan, J. R., Colt, J. S., & Hartge, P. (2006). Risk of non-hodgkin's lymphoma and nitrate and nitrate from drinking water and diet. *Epidemiology*, 17, (4), 375-382.
- Ward, M. H., deKok, T. M., Levallois, P., Brender, J., Gulis, G., Nolan, B. T., & VanDerslice, J. (2005). Workgroup report: Drinking-water nitrate and health-recent findings and research needs. *Environmental Health Perspectives*, 113 (11), 1607-1614.
- Ward, M. H., Cantor, K. P., Riley, D., Merkle, S., & Lynch, C.F. (2003). Nitrate in public water supplies and risk of bladder cancer, *Epidemiology*, 14, 183-190.
- Ward, M. H., Mark, S. D., Cantor, K. P., Weisenburger, D. D., Correa-Villasenor, A., & Zahm, S. H. (1996). Drinking water nitrate and the risk of non-hodgkin's lymphoma. *Epidemiology*, 7, (5), 465-471.
- Weisenburger, D. D. (1990). Environmental epidemiology of non-hodgkin's lymphoma in eastern Nebraska. *American Journal of Industrial Medicine*, 18, 303-305.
- Weyer, P. J., Cerhan, J. R., Kross, B.C., Hallberg, G. R., Kantamneni, J., Breuer, G., Jones, M. P., Zheng, W., & Lynch, C. F. (2001). Municipal drinking water nitrate level and cancer risk in older women: The Iowa women's health study. *Epidemiology*, 12, (3), 327-338.
- Winchester, P. D., Huskins, J., & Ying, J. (2009). Agrichemicals in surface water and birth defects in the United States. *Acta Paediatrica*, 98, 664-669.

- Wisconsin Groundwater Coordinating Council, Report to the Legislature. (2006). Retrieved November 1, 2009 from <http://dnr.wi.gov/org/water/dwg/gcc/rtl/2006report.pdf>.
- World Health Organization. (2007). Nitrate and nitrite in drinking- water. Retrieved November 20, 2009 from http://www.who.int/water_sanitation_health/dwq/chemicals/nitratenitrite2ndadd.pdf.
- U. S. EPA. Integrated Risk Information System (IRIS): Nitrate (CASRN 1497-55-8). Washington, D.C: U.S. Environmental Protection Agency. Retrieved November 16, 2009 from <http://www.epa.gov/NCEA/iris/subst/0076.htm>.
- Yang, C. Y., Wu, D. C., & Chang, C. C. (2007). Nitrate in drinking water and risk of death from colon cancer in Taiwan. *Environmental International*, 33, 649-653.
- Yang, C. Y, Cheng, M, F., Tsai, S. S., & Hsieh, Y. L. (1998). Calcium, magnesium, and nitrate in drinking water and gastric cancer mortality. *Japanese Journal of Cancer Research*, 89, (2), 124-130.
- Zeegers, M. P., Selen, R. F. M., Kleinjans, J. C. S., Goldbohm, R. A., & van den Brandt, P. A. (2006). Nitrate intake does not influence bladder cancer risk: The Netherlands cohort study. *Environmental Health Perspectives*, 114, (10), 1527-1531.
- Zuane, J. (1997). *Handbook of Drinking Water Quality*. (2nd ed.). John Wiley & Sons. Inc. New York, New York.

APPENDIX A
GIS MAP, LA CROSSE COUNTY LAB NITRATE LEVELS FOR LAST TEN YEARS

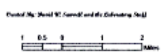
La Crosse County Lab Nitrate Levels For Last 10 Years



NITRATE NITROGEN is a chemical that is present in the ground water in La Crosse County and is used as a nutrient for plants. It is a natural part of the nitrogen cycle. The amount of nitrate in the ground water varies from year to year. It also is an indicator of potential contamination of the ground water. The amount of nitrate in the ground water is measured in milligrams per liter (mg/L). The Wisconsin Department of Natural Resources has established a level of 10 mg/L as a maximum contaminant level (MCL) for drinking water.

A potential source of nitrate in the ground water is the use of fertilizers. Fertilizers contain nitrogen, which can be converted to nitrate in the soil. Nitrate can then move into the ground water. Other sources of nitrate in the ground water include animal manure and septic systems. The Department of Natural Resources is currently conducting a study to determine the sources of nitrate in the ground water in La Crosse County.

- Nitrate Levels**
- Result**
- 0- 1.99 mg/L Safe
 - 2- 10 mg/L Action Level
 - >10 mg/L Health Concern MCL
- Municipality Limits



APPENDIX B
RESEARCH QUESTION AND SURVEY ITEM ALIGNMENT

RQ 1. How do private well owners become aware about nitrate well water testing?

8. Are you aware that you can have your well water tested for nitrates?

yes no

9. If yes to the previous question-how did you learn about nitrate well water testing?
(Please check all that apply)

- real estate transaction
- doctor or health care provider
- neighbor
- media (newspaper, TV, radio)
- La Crosse County Health Department
- other (Please specify _____)

RQ 2. What is the understanding about the cause of groundwater contamination among private well owners?

21. In your opinion, what is the greatest source of nitrate groundwater contamination?
(Please check only one response)

- use of agricultural fertilizers
- application of animal wastes (i.e., manure)
- use of fertilizers for private residences (i.e., non-agricultural)
- natural atmospheric sources
- septic system leakage
- application of bio-solids (e.g., land applied sewage, municipal sludge, whey)
- other (Please specify: _____)

RQ 3. What sources serve as information for private well owners to learn about their private well?

13. In the past if you had a question about your private well-how did you get information? (Please check all that apply)

- call the local Health Department
- obtain a well construction report
- contact real estate or seller of home
- contact well maintenance provider
- other (Please specify _____)
- none of the above because I have never had a question about my private well

14 & 15. Rank how likely you are to use the following sources to obtain general information about your **well and well water testing?**
(1 indicating most likely through 6 indicating least likely)

- mailed flyer or brochure
- newspaper
- radio
- television
- La Crosse County Health Department website
- Wisconsin Department of Natural Resources website

RQ 4: What prompts private well owners to test for nitrate?

16. Have you tested your well water for nitrate?
yes no

17. If you answered “yes” to the previous question (#16), when was the last time you had your well water tested for nitrate?

- less than a year ago
- 1-2 years ago
- 3-5 years ago
- 6-10 years ago
- greater than 10 years ago

18. If “yes” to the previous question, what prompted you to test your well water?

(Please check all that apply)

- neighbor’s test results
- doctor or health care provider recommendation
- La Crosse County Health Department recommendation
- saw noticeable changes in my water (Please describe changes: _____)
- other (Please specify: _____)

RQ 5. What barriers prevent private well owners from testing their private well water for nitrate?

19. If you have **not** tested your well water for nitrate, why is that so?
(Please check any one that applies)

- cost
- were not aware of nitrate well water testing
- inconvenience and time issues
- no health problems or noticeable changes in water
- lack of information about testing
- other (Please specify _____)

RQ 6. What percent of private well owners think it is important to test their private well water for nitrate and why?

10. How important do you think it is to test your well water for nitrate?
(Please check **only one** response)

- very important
- somewhat important
- not at all important

11. If you answered “very important” or “somewhat important”-what do you think is the most important reason to test private well water for nitrate?

(Please check only one response)

- for water quality and safety
- for routine well maintenance
- for health of infants living in household
- for pregnant women in household or woman of childbearing age
- other (Please specify _____)

12. If you answered “not at all important” to question 10-why do you think it’s not important to test private well water for nitrate?

(Please check only one response)

nitrate is not a health issue

nitrate does not affect water quality

testing for nitrate is not necessary

other (Please specify_____)

RQ 7. To what degree are private well owners concerned about nitrate groundwater contamination?

20. To what degree are you concerned about nitrate well water contamination in La Crosse County?

(Please check only one response)

very concerned

somewhat concerned

not concerned

APPENDIX C
CONTENT VALIDATION JURY PANEL

Content Validation Jury Panel

Henry Anderson, M.D. Chief Medical Officer, Wisconsin Division of Public Health

Elizabeth Heinen, Drinking & Groundwater Specialist, Wisconsin Department of Natural Resources

Kevin Masarik, Groundwater Education Specialist, Central Wisconsin Groundwater Center

Carla Schubert, MS, Researcher EpiSense Program, University of Wisconsin-Madison

Lori Severtson, R.N, Ph. D., Assistant Professor University of Wisconsin-Madison School of Nursing

APPENDIX D
COVER LETTER AND SURVEY “ASSESSMENT OF WELL WATER TESTING
FOR NITRATE”

ASSESSMENT OF WELL WATER TESTING FOR NITRATE

Dear Resident:

You are one of a group of La Crosse County residents randomly selected to participate in a survey designed to assess awareness about nitrate well water testing among private well owners in La Crosse County. This survey is part of my master's thesis research at the University of Wisconsin-La Crosse. Your answers combined with others will provide useful information to better assist in the educational and public outreach activities aligned with nitrate well water testing. Your survey answers will be used in combination with all other responses and thus remain strictly confidential. Participation in this survey is voluntary. Anyone 18 years or older who is the homeowner may fill out the survey. Completing and returning this survey will indicate your consent to be involved in this process.

If you have any questions about the survey, please contact:

Meghan O'Donnell
32524 Nordic Court
Rushford, MN 55971
(608) 397-6859
odonnell.megh@students.uwlax.edu

Jim Steinhoff
La Crosse County Health Department Laboratory Supervisor, Thesis Committee Member
300 4th Street N
La Crosse, WI 54601
(608) 785-9733
steinhoff.jim@co.la-crosse.wi.us

Dr. Gary Gilmore
Thesis Committee Chair
University of Wisconsin-La Crosse
201 Mitchell Hall
La Crosse, WI 54601
(608) 785-8163
gilmore.gary@uwlax.edu

The survey should take only about 10 minutes to complete. After you have finished, please use the pre-paid envelope to return the survey on or before Friday, March 19, 2010. We greatly appreciate your participation.

Thank you for your time.

Sincerely,

Meghan O'Donnell
MPH Candidate

ASSESSMENT OF WELL WATER TESTING FOR NITRATE

1. Age of homeowner filling out survey (Please check **only one** response):

- 18-29
- 30-39
- 40-44
- 45-49
- 50-59
- 60-75
- 76 or older

2. Age of family members in home. Please list ages: _____

3. Location of home (Please check **only one** response):

- on agricultural or farm land
- countryside, village, or town (not on agricultural or farm land, non-city location)

4. Number of years in current home. Please specify: _____ years

5. Age in years of well. Please specify: _____ years

6. Depth in feet of well. Please specify: _____ feet

Note: To determine the depth of your well, use the Wisconsin Department of Natural Resources website:

[http://prodoasext.dnr.wi.gov/inter1/watr\\$.startup](http://prodoasext.dnr.wi.gov/inter1/watr$.startup)

7. Primary drinking water source (Please check **only one** response):

- regular tap water (non-filtered)
- bottled water
- water hauled from another source
- other (Please specify: _____)

8. Are you aware that you can have your well water tested for nitrates?

- yes
- no

* If you answered “yes” please proceed to question 9, if you answered “no” please skip to question 10.

9. If you answered “yes” to the previous question, how did you learn about nitrate well water testing?

(Please check **all** that apply)

- real estate transaction
- doctor or health care provider
- neighbor
- media (e.g., newspaper, TV, radio)
- La Crosse County Health Department
- other (Please specify:_____)

10. How important do you think it is to test your well water for nitrate?

(Please check **only one** response)

- very important
- somewhat important
- not at all important

11. If you answered “very important” or “somewhat important”, what do you think is the **most important reason** to test your private well water for nitrate?

(Please check **only one** response)

- for water quality and safety
- for routine well maintenance
- for health of infants living in household
- for pregnant woman in household or woman of childbearing age
- other (Please specify:_____)

12. If you answered “not at all important” to question 10, why do you think it’s **not important** to test private well water for nitrate? (Please check **only one** response)

- nitrate is not a health issue
- nitrate does not affect water quality
- testing for nitrate is not necessary
- other (Please specify:_____)

13. In the past, if you had a question about your private well, how did you get the information? (Please check **all** that apply)

- I called the local Health Department
- I got a copy of my well construction report
- I got information from my real estate or seller of my home
- I contacted the well driller or pump installer
- other (Please specify: _____)
- none of the above because I have never had a question about my private well

14. Rank how likely you are to use the following sources to obtain general information about your **well**?
(1 indicating most likely through 6 indicating least likely)

- mailed flyer or brochure
- newspaper
- radio
- television
- La Crosse County Health Department website
- Wisconsin Department of Natural Resources website

15. Rank how likely you are to use the following sources to obtain general information about **well water testing**?
(1 indicating most likely through 6 indicating least likely)

- mailed flyer or brochure
- newspaper
- radio
- television
- La Crosse County Health Department website
- Wisconsin Department of Natural Resources website

16. Have you tested your well water for nitrate?
 yes no

* If you answered "no" please skip to question 19.

17. If you answered "yes" to the previous question (#16), when was the last time you had your well water tested for nitrate?

- less than a year ago
- 1-2 years ago
- 3-5 years ago
- 6-10 years ago
- greater than 10 years ago

18. If you answered “yes” to the previous question (#16), what prompted you to test your well water? (Please check **all** that apply)

- neighbor’s test results
- doctor or health care provider recommendation
- La Crosse County Health Department recommendation
- saw noticeable changes in my water (Please describe changes: _____)
- other (Please specify: _____)

19. If you have **not** tested your well water for nitrate, why is that so?
(Please check **all** that apply)

- cost
- were not aware of nitrate well water testing
- inconvenience and time issues
- no health problems or noticeable changes in water
- lack of information about testing
- other (Please specify: _____)

20. To what degree are you concerned about nitrate well water contamination in La Crosse County?
(Please check **only one** response)

- very concerned
- somewhat concerned
- not concerned

21. In your opinion, what is the greatest source of nitrate groundwater contamination in La Crosse County?
(Please check **only one** response)

- use of agricultural fertilizers
- application of animal wastes to land (i.e., manure)
- use of fertilizers for private residences (i.e., non-agricultural)
- natural atmospheric sources
- septic system leakage
- application of bio-solids (e.g., land applied sewage, municipal sludge, whey)
- other (Please specify: _____)

APPENDIX E
CONTENT VALIDATION JURY RESULTS SUMMARY

CONTENT VALIDATION JURY RESULTS SUMMARY

Content Validation Scale Values

1. NOT ACCEPTABLE: The item has no value as a statement for revealing the respondent's knowledge, awareness, and practice related to nitrate well water testing.
2. SOMEWHAT ACCEPTABLE: The item has some value as a statement for revealing the respondent's knowledge, awareness, and practice related to nitrate well water testing.
3. ACCEPTABLE: The item is valuable as a statement for revealing the respondent's knowledge, awareness, and practice related to nitrate well water testing.
4. VERY ACCEPTABLE: The item is very valuable as a statement for revealing the respondent's knowledge, awareness, and practice related to nitrate well water testing.
5. INDESPENSIBLE: The item is absolutely necessary as a statement for revealing the respondent's knowledge, awareness, and practice related to nitrate well water testing.

(Excerpted from: Gilmore, G.D. The Development, Implementation, and Evaluation of a Family Education Program Incorporating the Concept of Prevention. Knoxville: The University of Tennessee. 1974, 232pp. Dissertation Abstracts International, 35: 2864-B, 1974.)

SURVEY QUESTION	RANGE	AVERAGE RATING
<p>Are you aware of the availability of nitrate well water testing in La Crosse County?</p> <p>Revised: Are you aware that you can have your well water tested for nitrates?</p>	2-5	4.2
<p>If you answered “yes” to the previous question, how did you learn about nitrate well water testing?</p>	3-5	5.2
<p>Do you think it is important to test private well water for nitrate?</p> <p>Revised: How important do you think it is to test your well water for nitrate?</p>	2-5	3.8
<p>If you answered “yes” to the previous question, why do you think it’s important to test private well water for nitrate?</p> <p>Revised: If you answered “very important” or “somewhat important”, what do you think is the most important reason to test your private well water for nitrate?</p>	1-5	3.2
<p>If you answered “no” to question 4, why do you think it’s not important to test private well water for nitrates?</p> <p>Revised: If you answered “not at all important” to question 10, why do you think it’s not important to test private well water for nitrate?</p>	1-5	3.2
<p>In the past, if you had a question about your private well, how did you get information?</p>	4-5	4.2

<p>How likely would you use the following sources to obtain general information about your private well?</p> <p>Revised: Rank how likely you are to use the following sources to obtain general information about your well?</p>	2-5	3.6
<p>How likely would you use the following sources to obtain general information about well water testing?</p> <p>Revised: Rank how likely you are to use the following sources to obtain general information about well water testing?</p>	2-5	3.6
<p>Have you tested your well water for nitrate?</p> <p>Added follow-up question: If you answered “yes” to the previous question (#16), when was the last time you had your well water tested for nitrate?</p>	5-5	5
<p>If you answered “yes” to the previous question, what prompted you to test your well water?</p>	3-5	4.4
<p>If you have not tested you well water for nitrate, what has prevented you from testing?</p> <p>Revised: If you have not tested your well water for nitrate, why is that so?</p>	2-5	4.4
<p>To what degree are you concerned about nitrate well water contamination in La Crosse County?</p>	3-5	4
<p>In your opinion, what is the primary cause of nitrate groundwater contamination in La Crosse County?</p> <p>Revised: In your opinion, what is the greatest source of nitrate groundwater contamination in La Crosse County?</p>	2-5	3.2

APPENDIX F
AWARENESS AND TESTED CROSSTABULATION RESULTS

Awareness * Tested Crosstabulation

			Tested		Total
			No	Yes	
Awareness	No	Count	22	0	22
		Expected Count	8.9	13.1	22.0
		% within Awareness	100.0%	.0%	100.0%
		% within Tested	33.3%	.0%	13.4%
	Yes	Count	44	98	142
		Expected Count	57.1	84.9	142.0
		% within Awareness	31.0%	69.0%	100.0%
		% within Tested	66.7%	100.0%	86.6%
Total	Count	66	98	164	
	Expected Count	66.0	98.0	164.0	
	% within Awareness	40.2%	59.8%	100.0%	
	% within Tested	100.0%	100.0%	100.0%	

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	37.728 ^a	1	.000	.000	.000	
Continuity Correction ^b	34.912	1	.000			
Likelihood Ratio	45.276	1	.000	.000	.000	
Fisher's Exact Test				.000	.000	
Linear-by-Linear Association	37.498 ^c	1	.000	.000	.000	.000
N of Valid Cases	164					

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 8.85.

b. Computed only for a 2x2 table

c. The standardized statistic is 6.124.