2015

# Nitrate in Private Wells:Knowledge, oppinions,and Perceptions of Stakeholders

Augustus D. JaJa
*Walden University*

# Walden University

College of Health Sciences

This is to certify that the doctoral dissertation by

Augustus Jaja

has been found to be complete and satisfactory in all respects,
and that any and all revisions required by
the review committee have been made.

Review Committee
Dr. Raymond Thron, Committee Chairperson, Public Health Faculty
Dr. Mark White, Committee Member, Public Health Faculty
Dr. Mary Lou Gutierrez, University Reviewer, Public Health Faculty

Chief Academic Officer
Eric Riedel, Ph.D.

Walden University
2015

Abstract

Nitrate in Private Water Wells: Knowledge, Opinions, and

Perceptions of Stakeholders

by

Augustus JaJa

MBA, University of Phoenix, 2003

BS, Chemistry, Langston University, OK, 2003

BS, Environmental Health Science, East Central University, OK, 2000

AS, Environmental Science, Rose State College, OK, 1996

Dissertation Submitted in Partial Fulfillment

of the Requirements for the Degree of

Doctor of Philosophy

Public Health

Walden University

February 2015

Abstract

The purpose of this quantitative study was to examine data describing nitrate concentration and cases of congenital cardiac defects. Residents with private wells and other stakeholders need data to make informed environmental decisions about the adverse health implications of nitrate contamination of private well water. Researchers have examined the exposure of nitrate in contaminated groundwater, but they have not examined nitrate levels in unregulated water systems. This gap in the literature highlighted the need to provide nitrate data for future research and private well users. Guided by the social ecological model, a quantitative, cross-sectional, nonexperimental design was used to survey 231 adult participants about community perceptions of stakeholders' collaboration about groundwater and the sustainability of private water wells. Multiple linear regression was used to test the hypotheses. Survey results showed that gender, age group, and distance from animal waste sites or farmland were associated with barriers to community collaboration to achieve groundwater sustainability. Use of private wells for irrigation and distance from animal waste sites or farmland were associated with community members' perceptions of community collaboration to achieve groundwater sustainability. Community perceptions and barriers to stakeholders' collaboration were not affected by any demographic factors. The data will facilitate the design and implementation of effective public health outreach services for private well users. The implications for positive social change include increased understanding of stakeholders' perceptions of private well nitrate contamination and reduction of the risk factors for birth defects.

# Nitrate in Private Water Wells: Knowledge, Opinions, and Perceptions of Stakeholders

by

Augustus JaJa

MBA, University of Phoenix, 2003

BS, Chemistry, Langston University, OK, 2003

BS, Environmental Health Science, East Central University, OK, 2000

AS, Environmental Science, Rose State College, OK, 1996

Dissertation Submitted in Partial Fulfillment

of the Requirements for the Degree of

Doctor of Philosophy

Public Health

Walden University

February 2015

## Dedication

I would like to dedicate this dissertation to my wife, Catherine JaJa. Without your belief in me and all of your love and support, the journey would have been more difficult. To my parents, the late Mr. Job Dienye JaJa and Mrs. Alice Job Dienye JaJa, I thank you for instilling in me early in life the belief that I could do anything that I set my mind to with hard work, dedication, and perseverance. To our children, Jennifer JaJa, Dinnah JaJa, and Denzel JaJa, I thank you for bearing with me over the years as I went through this process. Finally, I give thanks to God Almighty, from whom all things are possible.

## Acknowledgments

I want to thank Dr. Raymond W. Thron, my committee chair, for his encouragement and support when I could see nothing in front of me but frustration. I am very fortunate to have found someone with your expertise and guidance to help me to navigate this process.

I want to thank Dr. Mark White, my second committee member, for believing in me and helping me to develop the manuscript. The only way that I can repay you is to pass your wisdom on to others. I also want to acknowledge Dr. David Mulhearn for giving me permission to modify and use the survey instrument that he developed. Finally, I want to express my appreciation to Dr. Mary-Lou Gutierrez, my university research reviewer, for guiding me in this challenging process. I cannot thank you enough for all that I learned from you.

Table of Contents

List of Tables

List of Figures

Chapter 1: Introduction to the Study

## Introduction

Researchers have examined exposure to contaminated groundwater, but they have not examined nitrate levels in unregulated water systems. Many infants born with such defects as congenital cardiac defects, central nervous system (CNS) malformation, neural tube defects, and abdominal wall defects (Arbuckle, 1988; Brender, Olive, Felkner, Suarez, Marckwardt, et al., 2004; Croen, Todoroff, & Shaw, 2001; Mattix, Winchester, & Scherer, 2007) have medical conditions replete with challenges.

Potential threats to groundwater quality are a public health concern that could affect the health of a community, especially in rural areas, where it is not common practice for private well users to test for contaminants (DeSimone, 2009; Embrey & Runkle, 2006). For instance, the United States has no universal standards for testing private wells (Imgrund, Kreutzwiser, & de Loë, 2011), even in real estate transactions (Hoppe, Harding, Staab, & Counter, 2011; Rogan & Brady, 2009). The American Water Works Association and the Groundwater Water Association have programs that recommend routine testing for private well users.

Although individual states have standards for testing private wells for environmental contaminants, many governmental jurisdictions have their own standards. The lack of a uniform standard for private well testing is because there are no federal or state regulations on private wells in the United States (Imgrund et al., 2011); however, some states have started to move in this direction. For well owners, inconvenience, lack of awareness, and time are the challenges to private well testing (Hexemer et al., 2008).

However, despite these barriers, it is important to test all public and private wells for nitrates because a high concentration of nitrate in groundwater has been linked to such adverse health outcomes as methemoglobinemia, birth defects, and cancer (Arbuckle, 1988; Fewtrell, 2004; Manassaram, Backer, & Moll, 2006). The purpose of this study was to determine how individuals perceive environmental resources and natural hazards. The development of public policy that increases awareness of groundwater contaminants in rural communities could help to inform the users of private wells in Oklahoma.

## Background of the Study

Based upon a review of the literature, it became evident that although researchers have examined the exposure of nitrate in contaminated groundwater, they have not examined nitrate levels in unregulated water systems. Many infants born with defects such as congenital cardiac defects, CNS malformation, neural tube defects, and abdominal wall defects (Arbuckle, 1988; Brender, Olive, Felkner, Suarez, Marckwardt, et al., 2004; Croen et al., 2001; Mattix et al., 2007) have medical conditions replete with challenges.

Nitrate, a common chemical in fertilizer, is pervasive throughout the environment and is regularly detected in groundwater (McElroy et al., 2008). Other contributors of nitrate include atmospheric deposition, livestock, septic systems, land application of municipal wastewater, and biosolids (Katz, Sepulveda, & Verdi, 2009). Researchers have shown that nitrates are essential body nutrients that also can be found in lettuce, spinach, beets, and meat products (Reinik et al., 2005; Zeegers, Selen, Kleinjans, Goldbohm, & van den Brandt, 2006). This increase in the amount of nitrate that percolates into groundwater is of public health concern, especially in rural areas where private wells are unregulated (Criss & Davisson, 2004; Freedman, Cantor, Ward, & Helzlsouer, 2000). This nitrate footprint, along with the adverse health effects of its presence in soil and water, presents a challenge to private well owners because private wells are not regulated and are not required to be tested by the U.S. Environmental Protection Agency (USEPA, 2012c, 2013).

In Oklahoma, public wells or public water supplies are regulated by the USEPA (2012c) and the Oklahoma Department of Environmental Quality (ODEQ, 2006); they present a low risk to users. Households with private wells might be at greater risk of methemoglobinemia and might not be aware of their exposure to contaminants (Postma, Butterfield, Odom-Maryon, Hill, & Butterfield, 2011; USEPA, 2012b, 2013). Private wells can be contaminated by anthropogenic and natural sources, such as agricultural chemicals and atmospheric nitrogen. Nitrate contamination of drinking water has implications for human health, one of which is birth defects in infants (Arbuckle, 1988; Brender et al., 2013; Fewtrell, 2004).

According to Dan-Hassan, Olasehinde, Amadi, Yisa, and Jacob (2012), nitrogen comprises about 80% of the air in the atmosphere and exists in the soil as NO2, NO3, NH4, NH3, and organic nitrogen (organic-N). The forms of nitrogen commonly measured in private wells include nitrate (NO3), nitrite (NO2), and ammonia (NH3) ions. Chemically, nitrate forms when one nitrogen and three oxygen ions combine; plant decay, fertilizers, and naturally occurring nitrate are sources (Albertin, Sickman, Pinowska, & Stevenson, 2012; Lingytė & Česonienė, 2009). Nitrates are transported through soil by leaching because of its high mobility (Burkart & Stoner, 2007; Dan-Hassan et al., 2012; Szajdak, Życzyńska-Bałoniak, Jaskulska, & Szczepański, 2009; Yang, Guirui, Chunyan, & Pei, 2012).

Anthropogenic actions from point and nonpoint sources such as wastewater treatment plants, fertilizer use, and animal waste might be contributing to a nitrate concentration above 10 mg/L, which is the USEPA's (2007) maximum contaminant level (MCL) of nitrate in drinking water (Manassaram et al., 2006; Oklahoma Water Resources Board [OWRB], 2011). Anthropogenic activities are the most visible human source of nitrate contamination (Mendes et al., 2012; Shekofteh et al., 2013; Sunitha, Reddy, & Reddy, 2012). Nitrogen is essential to plant growth, but when the nitrogen in the soil (i.e., soil that has been exposed to nitrogen-rich fertilizer) surpasses the plant demand and the denitrification capacity of the soil, nitrogen can then leach into groundwater, mainly as nitrate (Lingytė & Česonienė, 2009; Shekofteh et al., 2013; Van Bochove et al., 2007).

Nitrate in private wells might be an indicator of poor water quality, and other contaminants might be in groundwater if the source of the nitrate is anthropogenic. Similarly, nitrate contamination of surface water poses health and environmental concerns, one of which can be birth defects (Arbuckle, 1988; Fewtrell, 2004; Winchester, Huskins, & Ying, 2009). Nitrate is soluble in water and can migrate to surface water via discharge of groundwater during base flow conditions (G. Kim, Lee, Lim, Jung, & Kong, 2010; Speiran, 2010). In essence, the prevention of groundwater contamination is a mitigation action that also protects surface water (G. Kim et al., 2010).

Oklahomans rely on groundwater, or water from aquifers, for their household needs (U.S. Geological Survey, 2013). Some households get their drinking water from surface water sources. However, no groundwater is immune to contamination. To protect this commodity for future generations, it is imperative that private well owners' right to ownership of the water under their property extends to responsibilities to protect this resource. For these stakeholders, including private well owners and governmental agencies, to make informed decisions on how best to protect the watershed, the risks of inaction on the part of private well owners and the health implications of not regulating private wells should be communicated to private well owners.

Groundwater is an important water source for Oklahoma's rural residents. Riparian rights give property owners in Oklahoma the rights to use the water under their land (Dellapenna, 2011; Mittelstet, Smolen, Fox, & Adams, 2011). Likewise, water allocation in the United States is governed by state law rather than federal law, unless overriding public interest supersedes individual rights for the public good (Craig, 2010; Dellapenna, 2011). Groundwater in Oklahoma contributes to more than 60% of all water consumed in the state (Osborn, Eckenstein, & Koon, 1998), whereas surface water sources contribute about 40%. Of this groundwater, 570 million gallons are used by 20,000 homeowners for household or yard use (ODEQ, 2010). The ODEQ (2010) records on private well nitrate have shown that in certain wells, the nitrate level has exceeded the MCL of 10 mg/L.

The Safe Drinking Water Act of 1974 (SDWA, as cited in USEPA, 2006) guaranteed that individuals living in the United States have the right to safe drinking water that is free of contaminants and meets public health and safety requirements. The regulatory standard requires that publicly owned water systems be monitored regularly to ensure that they are in compliance with MCLs for chemicals, nutrients, heavy metals, and any other water contaminants that can adversely affect human health. However, for the approximately 5 million people in the United States who rely on private wells, safe drinking water might not be available. Most of these individuals live in rural communities, and the SDWA does not cover private wells (Backer & Tosta, 2011; Balazs, Morello-Frosch, Hubbard, & Ray, 2011).

Researchers have identified the health effects of exposure to nitrate in drinking water (Manassaram et al., 2006; McElroy et al., 2008; Ward et al., 2005). In epidemiological studies, researchers also have delineated unclear results from nitrate exposure and intrauterine growth retardation (Bukowski, Somers, & Bryanton, 2001); the increased incidence of sudden infant death syndrome (George et al., 2001); the increased risk of CNS malformation (Arbuckle, 1988; Brender, Olive, Felkner, Suarez, Hendricks, et al., 2004; Croen et al., 2001; Dorsch, Scragg, McMichael Baghurst, & Dyer, 1984); and congenital cardiac defects (Cedergren, Selbing, & Källén, 2002; Gupta et al., 2008). However, environmental exposure is one of many variables to consider when making a link to the etiology of congenital cardiac defects (Cedergren et al., 2002; Zierler, Theodore, & Cohen, 1988). A map of private well nitrate data provided by the ODEQ (2010) is presented in Appendix A. Appendix B presents congenital cardiac defect data provided by the Oklahoma Birth Defects Registry (as cited in Pearson, 2011). These data are included to show the rate of congenital cardiac defects/1,000 births in Oklahoma.

As mentioned previously, many infants born with defects have medical conditions replete with challenges. Researchers who have studied nitrates have suggested that pollutants can have toxic effects on children (Manassaram et al., 2006; McElroy et al., 2008; Ward et al., 2005). Nevertheless, the use of alcohol, tobacco, and other substances also can increase the risk factors for poor health outcomes (Burd et al., 2007; Moons et al., 2009). These complexities, along with the challenges of nitrate exposure and congenital cardiac defects, led me to shift the focus of this study to private well owners to determine what compels them to make environmental decisions that could be driving the long-term sustainability of private water sources.

Congenital cardiac defects present a challenging disease, regardless of the time of manifestation. Congenital cardiac defects are the result of prenatal abnormal heart development (American Heart Association [AHA], 2012). Lifestyle choices, environmental exposure, occupational exposure, and genetic components might be linked to congenital heart defects. The Centers for Disease Control and Prevention (CDC, 2011a) identified congenital cardiac defects as the most common type of birth defect when compared to other types of birth defects. The morbidity rate is approximately 9 of every 1,000 newborns (AHA, 2012). The National Institutes of Health (NIH, 2011) reported that 35,000 babies are born with congenital heart defects**.** It is essential to look into what is responsible for congenital cardiac defects in children. However, determining the relationship (i.e., exposure assessment) between environmental exposure and adverse health outcomes is challenging. For this reason, I reported only on the prevalence of congenital cardiac defects in Oklahoma’s 77 counties.

Infants born with congenital cardiac defects present a challenge to parents. Of all birth defects, congenital cardiac defects are the most common. Although progress has been made, this disease continues to be a challenge not only to parents but also to scientists. The mortality rate for congenital cardiac defects is double that of childhood cancers in any given year in the United States (AHA, 2012; Brent, 2004). The causes of most congenital cardiac defects are still unknown (Brent, 2004), and they have a prevalence rate of 1% among live births in the United States (CDC, 2011a). Among Oklahoma newborns, congenital cardiac defects are present in 6% to 8% of cases/1,000 births (Oklahoma State Department of Health [OSDH], 2012), and they are the leading cause of death among children under the age of 1 year in Oklahoma. Congenital cardiac defects rank second in mortality rate for children between the ages of 1 and 4 years in Oklahoma (OSDH, 2003; National Birth Defects Prevention Network, 2010). Environmental exposure rates and adverse health outcomes in Oklahoma are similar to those in the rest the United States, especially among people who live in rural communities (CDC, 2011b; Rogan & Brady, 2009; USEPA, 2012b).

An average of 748 cases of congenital cardiac defects occurred annually between 1999 and 2008 (Pearson, 2011). Cardiovascular disease was the largest category of birth defects at 29.8%, followed by muscular defects at 24.3% and gastrointestinal and nervous defects at 13.95% and 8.5%, respectively. According to the Oklahoma Pregnancy Risk Assessment Monitoring System report (PRAMS, as cited in OSDH, 2012), between 1998 and 2008, changes in the prevalence of congenital anomalies were reported. For instance, the most prevalent categories of birth defects were congenital anomalies of the heart and circulatory system at 42%, an increase of about 12% from the previous decade. Musculoskeletal defects rose from 24% to 29% (OSDH, 2012). There also was a decrease in the prevalence of gastrointestinal defects from 13.5% to 3%, but CNS malformation increased 8.5% to 13% (OSDH, 2012; Pearson, 2010). Environmental, genetic, and maternal factors could be possible risk factors because about 70% of birth defects are unknown (OSDH, 2012; Pearson, 2010).

Scientists are debating the stringency of the current MCL of 10 mg/L of nitrate in drinking water , and it has been suggested that it should be lowered. On the other hand, some researchers have advocated that the MCL be raised, suggesting that there is sufficient evidence to increase the permitted concentration of nitrate in drinking water without increasing the risk to human health (Van Grinsven, Ward, Benjamin, & De Kok, 2006). Avery (1999) argued that raising the nitrate MCL to between 15 and 20 mg/L would not constitute a health risk. Wilson, Kabogo, Evans, and Burns (2003) asserted that the nitrate MCL could be raised to 100 mg/L.

Chronic health implications for drinking water nitrate have been inconclusive. Such implications have included congenital anomalies (Cedergren et al., 2002); intrauterine growth retardation (Bukowski et al., 2001); and an increased incidence of sudden infant death syndrome (George et al., 2001).On the contrary, other researchers (e.g., Avery, 1999; Van Grinsven et al., 2006; Wilson et al., 2003) have argued that investigations into some health risks on nitrate remain uncertain.

Literature supporting nitrate as a cause of these diseases has been scant and controversial. Given the lack of cohesive well water issues, there appears to be a need for research focusing on nitrate and other inorganic contaminants. Nitrate also can be a co-contaminant. Because private wells are unregulated, nitrate exposure in rural communities that get their drinking water from this source is a public health concern (Van Grinsven et al., 2006).

The review of the literature showed that researchers have conducted few empirical studies evaluating community members' perceptions of collaboration in, and barriers to, the management of health threats in private well water sources (Jones et al., 2006). There is a need for research to generate information on community members' perceptions of collaboration to achieve groundwater (i.e., private well water) sustainability and the perceived barriers to such collaboration among private well users in Oklahoma. Having a better understanding of the opinions, knowledge, and perceptions of the stakeholders will help to ensure a sustainable water system. The data generated from this study are expected to be useful to future researchers by providing an approach to outreach services that might have greater public health benefits for private well users.

## Problem Statement

Although researchers have examined nitrate exposure in contaminated groundwater, they have not examined nitrate levels in unregulated water systems. Private water well nitrate exposure is a public health concern (Manassaram et al., 2006; McElroy et al., 2008; Ward et al., 2005; Zeman et al., 2011). More than 5 million rural residents in the United States who depend on private well water have been exposed to nitrate at concentrations exceeding the 10 mg/L standard (Kite-Powell & Harding, 2006; USEPA, 2011). Knowledge of, opinions about, and perceptions about nitrate and the quality of private water well vary among stakeholders (Jones et al., 2006).

The lack of cohesive opinion about the quality of private well water has become a public health concern (Suvedi & Krueger, 2000). Private well owners should be aware of issues that affect water quality, groundwater resources, and the sources of their drinking water. Understanding stakeholders' opinions and perceptions might help to address the conflict of opinions among private well owners, increase public awareness about groundwater quality concerns, and promote environmental stewardship.

There has been little empirical research on private well owners' attitudes toward water quality in Oklahoma on whether and how the community and other stakeholders should collaborate on environmental decision making. One reason is that private wells are not regulated and are typically not tested (Backer & Tosta, 2011; Imgrund et al., 2011; Sabogal, 2010). The importance of stakeholders' collaborations and sustainability has been well documented (Backer & Tosta, 2011; Imgrund et al., 2011; Sabogal, 2010), but how stakeholders collaborate on private well water quality remains unclear. Without this knowledge, it is difficult to understand the characteristics and dynamics of the collaboration, as well as the possible impact of barriers to private well sustainability. This gap in the literature has created the need for more focused studies that will provide data for future researchers, thus supporting an approach to outreach services that might have public health benefits for private well users.

## Purpose of the Study

The purpose of this quantitative study was to examine data describing nitrate concentration and cases of congenital cardiac defects. I explored community members' perceptions of community collaboration as a way of sustaining private water wells. I sought to determine whether certain demographic variables (e.g., gender, home ownership and residence duration, education, and drinking water usage) influenced individual perceptions of the ways in which communities can collaborate to mitigate health threats in private well water sources or whether the variables revealed barriers that need to be removed.

I did not use the study to determine causal relationships or associations because of limitations of data or confounders. As such, this study can serve only as a springboard or to generate hypotheses for future research. I used a quantitative, nonexperimental design to (a) describe the community members' perceptions to achieve groundwater (private well) sustainability, (b) identify any perceived barriers to attain collaboration on mitigating health threats, and (c) explore the relationship between these perceptions and the demographic characteristics of the sample. The respondents answered the survey questions relating to relationships between and among the independent variables (IVs) and the dependent variables (DVs). Both types of DVs were continuous. The 10 IVs were age, gender, education, homeownership, length of stay in the area, distance from animal waste sites or agricultural property, use of private well, source of drinking water, membership in homeowners/landowners association, and desire to join homeowners/landowners association. The total perception score and the total barrier score were the DVs.

## Research Questions and Hypotheses

The study was guided by two research questions (RQs) and hypotheses:

1. What is the relationship between the community perceptions of stakeholders' collaboration and the demographic characteristics of the study sample (i.e., age, gender, education, homeownership, length of stay in the area, distance from animal waste sites or agricultural property, use of private well, source of drinking water, membership in homeowners/landowners association, and desire to join homeowners/landowners association)?

$H_{01}$: Community perceptions are not affected by any demographic factors of the sample (i.e., age, gender, education, homeownership, length of stay in the area, distance from animal waste sites or agricultural property, use of private well, source of drinking water, membership in homeowners/landowners association, and desire to join homeowners/landowners association).

$H_{a1}$: Community perceptions are affected by at least one of the demographic factors of the sample (i.e., age, gender, education, homeownership, length of stay in the area, distance from animal waste sites or agricultural property, use of private well, source of drinking water, membership in homeowners/landowners association, and desire to join homeowners/landowners association).

2. What is the relationship between community barriers to stakeholders' collaboration and the demographic characteristics of the study sample (i.e., age, gender, education, homeownership, length of stay in the area, distance from

animal waste sites or agricultural property, use of private well, source of drinking water, membership in homeowners/landowners association, and desire to join homeowners/landowners association)?

$H_{02}$: Community barriers to stakeholders' collaboration are not affected by any demographic factors of the sample (i.e., age, gender, education, homeownership, length of stay in the area, distance from animal waste sites or agricultural property, use of private well, source of drinking water, membership in homeowners/landowners association, and desire to join homeowners/landowners association).

$H_{a2}$: Community barriers to stakeholders' collaboration are affected by at least one of the demographic factors of the sample (i.e., age, gender, education, homeownership, length of stay in the area, distance from animal waste sites or agricultural property, use of private well, source of drinking water, membership in homeowners/landowners association, and desire to join homeowners/landowners association).

## Theoretical Constructs

The theoretical framework for the study was based upon the social ecological model, which has been used to explore the relationship between individuals and the environment in which they live (Glanz, Rimer, & Lewis, 2002; Stokols, 1996). According to this model, there is an association between a person's environment and the general effect of that environment on health (Glanz et al., 2002; Stokols, 1996). For instance, the environment is presumed not only to act as a potential source of toxins, hazards, and pathogens but also to be responsible for health information and social influences that can be used to achieve better health and well-being (Glanz et al., 2002; Stokols, 1996). For these reasons, the social ecological model has been used in public health to identify environmental causes of illness and social mediation that can be used to better protect human health (Glanz et al., 2002; Stokols, 1996).

Tanner (2009) defined environmental decision making as a process usually based upon "utilitarian models, which implies that people's decisions are influenced only by the outcomes" (p. 1). It is a decision-making ability based upon knowledge, moral and ethical understanding, responsibility, and experience regarding the relationship between human beings and the Earth (Tanner, 2009). It also provides a base from which to make environmental decisions that will benefit society at large (Balgopal & Wallace, 2009; Orr, 2004).

I did not use this model because the environmental decision-making model, which is based upon the utilitarian model and outcomes, does not recognize internal and external influences. The social ecological model enabled me to document the many variables that influenced stakeholders' decisions and might have supported or constituted barriers to health decisions. The model also explores and facilitates an understanding of the factors that can influence behavioral changes (Gazmararian, Curran, Parker, Bernhardt, & DeBuono, 2005; Green, Richard, & Potvin, 1996). For these reasons, the social ecological model was appropriate for this study.

## Definitions of Terms

*Aquifer:* An underground formation or group of formations in rocks and soils containing enough groundwater to supply wells and springs (USEPA, 2003).

*Base flow:* Groundwater seepage into a stream channel (Schilling & Zhang, 2004).

*Collaboration:* Stakeholders working together with the primary purpose of learning the environmental impact of contaminants on their source water, and how to improve water quality in their private wells, so as to make informed decisions about water resource management (Sabogal, 2010).

*Community sustainability:* Desire to meet present needs without compromising the quality for future generations (USEPA, 2012a).

*Contaminant:* Anything found in water (including microorganisms, minerals, chemicals, radionuclides, etc.) that might be harmful to human health (USEPA, 2003).

*Denitrification:* The biochemical reduction of nitrate or nitrite to gaseous nitrogen either as molecular nitrogen or as an oxide of nitrogen (USEPA, 2012c).

*Groundwater:* Water below the topsoil and above impervious rock (Rogan & Brady, 2009).

*Nitrification*: A microbial process by which reduced nitrogen compounds, primarily ammonia, are sequentially oxidized to nitrite and nitrate (USEPA, 2002).

*Nitrate:* Plant nutrient and fertilizer that enters water supply sources from fertilizers, animal feedlots, manures, sewage, septic systems, industrial wastewaters, sanitary landfills, and garbage dumps (USEPA, 2003).

*Private well water source:* Water supply that does not include public water sources (e.g., private and domestic wells owned by individuals; USEPA, 2003).

*Safe Drinking Water Act (SDWA)*: The SDWA (1974, as cited in USEPA, 2006) is the main federal law that ensures the quality of U.S. drinking water. Under the SDWA, the USEPA (2012a) sets standards for drinking water quality and oversees the states, localities, and water suppliers who implement those standards.

*Stakeholders:* Private wells owners, community leaders, and public policy officials (USEPA, 2011).

*Surface water:* Rainwater that collects in surface water bodies like oceans and lakes (USEPA, 2012b).

*Sustainable:* The availability of a safe and quality water supply for human beings and the ecosystem at large or streams (USEPA, 2011).

*Sustainable water resources:* “To ensure safe and sustainable water quality and the ability to protect human and ecosystem health by integrating social, economic, and environmental research for protecting and restoring water resources and their designated uses” (USEPA, 2012c, p. 20).

*Sustainability*: Capacity to endure (Sabogal, 2010).

## Assumptions

I assumed that there was an advantage in conducting a cross-sectional study, in that I could collect the data at one time and with and no need for follow-up activities (Creswell, 2009; Page, Cole, & Timmreck, 1995). I further assumed that the design would help me to collect information from the respondents pertaining to their perceptions of water quality and alternative water sources because the design was strongly rooted in theory. I also assumed that community collaboration can lead to groundwater or private well sustainability. The households in this case might have been able to provide the required information at the time of the survey, making attrition, as in longitudinal studies, unlikely (Rindfleisch, Malter, Ganesan, & Moorman, 2008). In addition, I required fewer participants to detect an association, and I had the flexibility to explore numerous health outcomes and related risk factors at the same time (Rindfleisch et al., 2008).

## Limitations

The study had several limitations: (a) The problem of nitrate in Oklahoma private water wells might have been unique to the state; (b) a cross-sectional design was appropriate for this study because of its descriptive and exploratory nature (Creswell, 2009), which allowed me to use my limited time and funding to gather, analyze, and interpret data from a sample; however, generalization of the study results was limited; and (c) individuals eligible to be in the sample might not have been willing to participate because it was voluntary, not mandatory. The study reflected only the views of those who participated. When the temporal nature of a phenomenon is not clear, it also is likely that intervening events could confound a follow-up study.

## Scope and Delimitations

The scope of this study was to examine the perceptions of private water well stakeholders and nitrate contamination. The research design was a survey of 231 participants over the age of 18 years who lived in Oklahoma at the time of the study. The results of this study might not be generalizable to other parts of the United States because conditions and other environmental factors might be different.

## Social Change Implications

This study might lead to positive social change in that it could provide (a) a better understanding of nitrate exposure in private wells, (b) more information on the evidence-based environmental decision-making process used to mitigate health threats through community collaboration, (c) an approach to outreach services that might provide greater public health benefits for Oklahoma private well users, and (d) a possible understanding of stakeholders' perceptions of private well nitrate contamination and the opportunity to reduce the risk factors for birth defects.

## Significance of the Study

This study is significant because there has been little empirical research on nitrate exposure from unregulated private well water sources. There is a need for sustained research and an environmental evaluation of nitrate-contaminated drinking water for populations using unregulated private wells. Environmental factors might play a role in the etiology of congenital cardiac defects (Cedergren et al., 2002; Zierler et al., 1988). Many infants born with defects such as congenital cardiac defects, CNS malformation, neural tube defects, and abdominal wall defects (Arbuckle, 1988; Brender, Olive, Felkner, Suarez, Hendricks, et al., 2004; Croen et al., 2001; Mattix et al., 2007) have medical conditions replete with challenges. The results of this study are expected to play a role in policy development, advocacy, and awareness of the issues that affect water quality, groundwater resources, and sources of their drinking water, a role that could be of public health benefit to rural communities.

## Summary and Transition

More than 5 million rural residents in the United States who depend on private well water have experienced exposure to nitrate at concentrations exceeding the 10 mg/L MCL (Kite-Powell & Harding, 2006; USEPA, 2011). There has been no research on private well owners' attitudes toward water quality in Oklahoma describing ways in which the community and other stakeholders could collaborate on environmental decision making (Robbins, 2012) because private wells are not regulated (Imgrund et al., 2011) and are not covered under the SDWA (1974, as cited in USEPA, 2006). The lack of agreement on the MCL of nitrate might pose a health concern and present an unclear platform in mitigating the problem of private well nitrate contamination and human health. A noncohesive agreement on the MCL of nitrate can be a challenge in the delivery of public health services and awareness about nitrate adverse health outcomes. The results could fill the gap in the literature and provide data for future researchers to help to ensure an approach to outreach services that will have public health benefits for private well users in Oklahoma.

Chapter 2 includes a review of the relevant literature on nitrate and community perceptions among the stakeholders. In Chapter 3, I describe the study design, target population, sample, setting, data collection and analysis, and ethical treatment of the participants. Chapter 4 includes the results and the data analysis. Chapter 5 presents an interpretation of the findings, limitations of the study, implications for social change, and recommendations for future research.

# Chapter 2: Literature Review

## Introduction

Researchers have suggested that nitrate can be toxic to children (Manassaram et al., 2006; McElroy et al., 2008; Ward et al., 2005). Researchers also have examined nitrate exposure in contaminated groundwater, but they have not examined nitrate levels in unregulated water systems. There has been little empirical research on nitrate exposure from unregulated private well water sources. There is a need for sustained research and an environmental evaluation of nitrate-contaminated drinking water for populations using unregulated private wells. Environmental factors might play a role in the etiology of congenital cardiac defects (Cedergren et al., 2002; Zierler et al., 1988). Many infants born with defects such as congenital cardiac defects, CNS malformation, neural tube defects, and abdominal wall defects (Arbuckle, 1988; Brender, Olive, Felkner, Suarez, Hendricks, et al., 2004; Croen et al., 2001; Mattix et al., 2007) have medical conditions replete with challenges.

The purpose of this study was to examine data on nitrate concentration and cases of congenital cardiac defects. I explored community members' perceptions of community collaboration as a way of sustaining private water wells. I sought to determine whether certain demographic variables (i.e., age, gender, education, homeownership, length of stay in the area, distance from animal waste sites or agricultural property, use of private well, source of drinking water, membership in homeowners/landowners association, and desire to join homeowners/landowners association) influenced individual perceptions of the ways in which communities collaborate to mitigate health threats in private well water sources, or whether the variables revealed barriers that need to be removed to ensure community collaboration. I did not use the study to determine causal relationships or associations because of data limitations or confounders. As such, the study can serve only as a springboard to generate hypotheses for future research. I used a quantitative, nonexperimental design to (a) describe the community members' perceptions about achieving groundwater (private well) sustainability, (b) identify any perceived barriers to collaborating on mitigating health threats, and (c) explore the relationship between these perceptions and the demographic characteristics of the sample.

To find literature for this study, I conducted searches using the following keywords: *nitrate*, *nitrite*, *groundwater*, *cardiac defects*, *human health*, *Oklahoma*, *water rights*, *stakeholders*, *knowledge, perception*, *sustainability*, and *cancer*. I also used the following databases: MEDLINE, CINAHL, Google Scholar, EPA, NIH, Academic Search EBSCO, and CDC. I restricted the scope to articles published within the last 5 years.

In this chapter, I describe and discuss the current concentration of nitrate in Oklahoma based upon information in the published literature. I review background information on groundwater nitrate exposure and the potential public health risks to human beings, especially among the rural population, who rely on private wells for their water. I highlight cases of congenital cardiac defects, as reported by the OSDH (2012). In addition, I discuss human interactions with nitrate, discuss identified risks, and point out potential risks that might require further research among private wells users exposed to nitrate concentrations above the recommended limit. Although some researchers have identified a link between nitrate in groundwater and the risk of infant methemoglobinemia and cancers of the digestive tract, there also has been disagreement. I present these disagreements in the review.

I also describe some general characteristics of and discuss the importance of groundwater quality. I discuss groundwater rules and the goals of the SDWA (1974, as cited in USEPA, 2006), which stipulated that U.S. groundwater must be safe from contaminants and meet minimum standards for drinking water. Next, I describe the geological formation and ecology of Oklahoma and discuss the agencies that are responsible for maintaining a sustainable environment in Oklahoma as well as the public health concern of nitrate exposure. I also discuss the cross-sectional design approach because such a design is commonly used to examine the relationship between community perceptions of the environment and stakeholders' perceptions of the community and their environments. I conclude the chapter with a discussion of relevant literature on nitrate and community perceptions among the stakeholders, along with a summary of key points relevant to this study.

## Review of Theoretical Framework

Theoretical frameworks provide a platform by which researchers can determine the most appropriate conceptual frameworks for their studies. Stakeholder theory provides a conceptual framework for analyzing the relationship among the varied interests of the stakeholders. The relevance of the core principle of the theory relates directly to the use of resources that are central to stakeholder interest management.

The theoretical framework of this study was the social ecological model. According to the social ecological model, there is an association between a person's environment and the general effect of the environment on health (Glanz et al., 2002; Stokols, 1996). For instance, the environment not only can be a potential source of toxins, hazards, and pathogens but also can be responsible for health information and social influences that can facilitate the achievement of better health and well-being. For these reasons, public health workers use the social ecological model to identify the environmental causes of illness and the social mediation that can be used to better protect human health (Glanz et al., 2002; Stokols, 1996).

In an effort to protect the public health community, I discussed restrictions on water use and collaboration as two methods of producing sustainable water supplies based upon the assumption that community collaboration is better than restrictions on water use. I also assessed community members' perceptions about the importance of and barriers to community collaboration. The participants, all of whom were residents of Oklahoma, completed a survey to assess these perceptions.

The social ecological model is a platform for stakeholders and the community to gain an in-depth understanding of the groundwater resources and for rural communities to understand not only social and ecological dependency but also the ways in which they can work to incorporate collaboration as the centerpiece of their environmental stewardship and groundwater protection. The social ecological theory might serve as a foundation for actions that will engage and encourage participatory citizens (i.e., residents of rural Oklahoma) to focus on how best to protect private well resources through collaboration rather than restrictive use of their groundwater resources as their alternative to private well or groundwater quality issues. Therefore, I used this theoretical framework to study the problem of nitrate in Oklahoma well water and evaluate the knowledge, opinions, and perceptions of a sample of residents to influence social interventions such as policy development, environmental education, health education, social behavior change, and modification.

## Prevalence and Incidence of Cardiac Defects

Congenital cardiac defects, the most common type of birth defect, are the result of abnormal heart development before birth, and they affect nine of every 1,000 newborns (AHA, 2012). The NIH (2011) reported that approximately 35,000 babies are born with congenital heart defects**.** The mortality rate for congenital cardiac defects doubles that of child hood cancers in any given year in the United States (AHA, 2012). From an epidemiological point of view, the association between congenital abnormalities and cancer has been well documented.

The association between congenital anomalies and tumors also has been well established (Altmann, Halliday, & Giles, 1998; Moore, Satgé, Sasco, Zimmermann, & Plaschkes, 2003). Comorbidities of cancer and congenital anomalies are the most likely among children with cancer (Zierhut, Murati, Holm, Hoggard, & Spector, 2011). The incidence of congenital cardiac defect could be significantly higher in patients with cancer (Ross, 2008), suggesting an unrecognized tumor predisposition syndrome in infants with cancer because researchers might have compared only the prevalence rate of congenital cardiac defects without focusing on whether infants with cardiac defects are predisposed to develop cancer later on in life.

Researchers also have suggested that future generations might be genetically predisposed to health implications related to cancer because of therapeutic cancer treatment that parents received as children (Byrne et al., 1998). Cardiac malfunctions of offspring might be the result of cancer treatments that parents received as infants. However, Winther et al. (2009) found no link between childhood cancer therapy and potential future health risk for future generation. Researchers have been unable to identify conclusively genetics and cancer treatments undergone in childhood as the source of congenital malformations (Boice et al., 2003; Green et al., 1996; Wyrobek et al., 2007). Irrespective of the risk factors for this disease, there continue to be health and social costs related to childhood disease. There is a need for research to determine the risk factors of environmental exposure to hazards, either in groundwater, air, and/or genetic predisposed precursors, that might constitute a health hazard to individuals later in life or might affect their offspring in years to come.

The causes of most congenital defects are unknown. One of the reasons the etiology of this malformation continues to elude researchers is because epidemiologic investigations have been inconsistent; the etiology of cancerous tumors could be environmental or genetic factors (Brent, 2004; Shi & Chia, 2001). Congenital cardiac defects lead to complications that could lead to death during the first year of life (Maria, Popescu, Cornitescu, Puiu, & Florescu, 2012). The morbidity and mortality rates of this disease are a public health concern, coupled with the teratogenic potential of many compounds found in groundwater, especially in private wells, that might contribute to the development of congenital anomalies. Researchers have identified an association between drinking water nitrate levels and the incidence of congenital anomalies (Arbuckle, 1988; Cedergren et al., 2002; Croen et al., 2001**;** Dorsch et al., 1984). Private well owners should be made aware of the risk factors of elevated nitrate levels and the possible adverse effect on human health. Such information and data will help to educate, inform, and allow private owners to make environmental decision that might lead to sustainable water resources for future generations.

In the United States and other countries, governments have a duty to protect their citizens by providing safe environments that are free from hazards. These responsibilities might include clean water, clean air, and a clean environment free of potential hazards. Oklahoma is no different from other U.S. states in regard to these responsibilities. The OSDH (2012) is responsible for monitoring the incidence and prevalence of congenital cardiac defects in the 77 counties of the state in which it operates. This responsibility extends to maintaining an active birth defects registry, an integral part of a public health surveillance program that monitors the status of children with birth defects born to women who are residents of Oklahoma. In Oklahoma, an average of 748 cases of congenital cardiac defects occurred annually between 1999 and 2008 (OSDH, 2012). Cardiovascular disease was the largest category of birth defects at 29.8%, followed by muscular defects at 24.3%, with gastrointestinal and CNS defects at 13.95% and 8.5%, respectively (OSDH, 2012).

According to PRAMS (OSDH, 2012), between 1998 and 2008, changes in the prevalence of the congenital anomalies were reported. The most prevalent birth defect categories of birth defects were congenital anomalies of the heart and circulatory system, an increase to 42% from 12% in the previous decade, and musculoskeletal defects, which increased from 24% to 29% (OSDH, 2012). There was a decrease in the prevalence of gastrointestinal defects from 13.5% to 3%, but CNS defects increased 8.5% to 13% (OSDH, 2012; Pearson, 2010). Environmental, genetic, and maternal factors could be a possible risk factor because approximately 70% of the reasons for birth defects are unknown (OSDH, 2012; Pearson, 2010). The etiology of birth defects could be either environmental or genetic. Pregnant women must be aware of the public health concerns about the potential role of environmental or genetic exposure as a risk factor. Such knowledge comes through research identifying the etiology of this disease for the benefit of the community.

Early identification of infants at risk of congenital cardiac defects allowed the OSDH (2003) to start early intervention programs to improve the outcomes of newborns with birth defects. The OSDH (2003) provides ongoing health care information to Oklahomans under the authority of the Oklahoma State Health Statute. Congenital cardiac defects are among the health information that the department provides to the public under this statute. According to the OSDH (2012), congenital cardiac defects are present in 6% to 8% of cases/1,000 births in Oklahoma; congenital malformations are the leading cause of death among children under the age of 1 year in Oklahoma (OSDH, 2003). Congenital cardiac defects ranks second in mortality for children between the ages of 1 and 4 years (OSDH, 2003). Such health information is important for public health officials to know because they are responsible for providing awareness to the population the most at risk for congenital malformations.

**Groundwater Nitrate**

Nitrate, a common chemical found in fertilizer, is pervasive in the environment and is detected regularly in groundwater. Nitrate is a form of nitrogen with an atom of nitrogen and three oxygen atoms (NO3) that exists as an ion. There are several sources of drinking water nitrate, including plant decay, fertilizers, and naturally occurring nitrate. Researchers have found that a nitrate concentration greater than 3.0 mg/L in groundwater comes from human sources such as fertilizer applications and animal waste, a concentration less than 0.2 mg/L originates from natural sources, and a concentration of nitrate between 0.21 and 3.0 mg/L can be attributed to both human influences or anthropogenic sources (Mueller & Helsel, 1996). The USEPA’s (2007) MCL for nitrate in drinking water is 10 mg/L.

Groundwater or water from an aquifer is the predominant source of water for most of rural Oklahoma. More than 56% of the total water use in Oklahoma comes from groundwater. Of this, 570 million gallons are used by 20,000 homeowners for household or yard use (Smithee, 2009).

ODEQ (2010) records on private well nitrate have shown that in certain wells, the nitrate level exceed the MCL of 10 mg/L. According to Smithee (2009), 625,000 Oklahomans rely on groundwater as their raw water source, and 200,000 residents of the state depend on groundwater as their source of drinking water. The growing population depend on groundwater because groundwater is their primary source of water in private wells. In Oklahoma, between 1900 and 1990, 29,789 wells were dug in Oklahoma. Smithee (2009) reported that between 1990 and 2006, 40,000 wells were dug in Oklahoma, compared with the approximately 30,000 wells construction for the 90–year span of 1900 to 1990. Private water wells are not subjected to the monitoring required by public water systems' drinking water supplies. Because regulatory agencies do not regulate private wells, the owners of private water wells need information that will enable them to make informed decisions about the quality of their drinking water.

Changes in groundwater quality might be a determinant of the health of a community, especially in rural areas, where it is not common practice for private well users to test for water contaminants. The lack of education regarding proper well maintenance and inconvenience for private well users are key barriers to private well stewardship (Hexemer et al., 2008). However, it is important to test all public and private wells for nitrate because a high concentration of nitrate in groundwater also has been linked to methemoglobinemia, birth defects, and cancer (Arbuckle, 1988; Fewtrell, 2004; Manassaram et al., 2006).

Researchers have identified health effects and nitrate exposure via drinking water (Manassaram et al., 2006; McElroy et al., 2008; Ward et al., 2005). In epidemiological studies, researchers also have delineated unclear results from nitrate exposure and intrauterine growth retardation (Bukowski et al., 2001); increased incidence of sudden infant death syndrome (George et al., 2001); increased risk of CNS defects (Arbuckle, 1988; Brender, Olive, Felkner, Suarez, Hendricks, et al., 2004; Croen et al., 2001; Dorsch et al., 1984); and congenital cardiac defects (Cedergren et al., 2002; Gupta et al., 2008). In U.S. private wells, water supplies are not regulated, even though most rural populations rely on it for their drinking water. Groundwater is not immune to contaminants and might be exposed to elevated nitrate levels that can place people at risk for methemoglobinemia.

The ubiquity of nitrate in the environment has been well documented. Nitrate is used in farming applications as a fertilizer and is a source of environmental nitrogen. Comly (1945) claimed that nitrate could be a potential risk factor for methemoglobinemia. Nitrate in the environment, food, and drinking water is not of great concern because it is relatively nontoxic; however, the subsequent conversion of nitrate to nitrite, a precursor for teratogenic and carcinogenic N-nitroso compounds, poses more of a concern. The current MCL established by the USEPA is 10 mg/L nitrate as nitrogen (USEPA, 2006).

Although some researchers have found a link between nitrate in groundwater and the risk for infant methemoglobinemia and cancers of the digestive tract, scientists have disagreed whether to raise or lower the MCL for drinking water nitrate, which is currently set at 10 mg/L by the USEPA. The health implications of nitrate continue to be controversial because of inconclusive evidence of disease causation (Powlson et al., 2008). Some scientists have suggested raising the MCL of nitrate in drinking water because the health impact of nitrate has been inconclusive, suggesting the need for more focused research (Powlson et al., 2008). This lack of consensus has heightened the need for evidenced-based research to identify an acceptable threshold for nitrate concentration in drinking water (Powlson et al., 2008).

Health concerns associated with nitrate might be long term or short term, depending on exposure. Researchers have noted that exposure to nitrate at a concentration above the MCL has been associated with increased risk for anencephaly, a form of developmental disorder that occurs during pregnancy. For example, Croen et al. (2001)'s study on the health implications of maternal periconceptional exposure to nitrate from drinking water and diet concluded that exposure to nitrate in drinking water at concentrations above the MCL of 10 mg/L has adverse health outcomes. On the other hand, there have been mixed results from studies evaluating nitrate and congenital malfunctions in newborns. Several researchers (Arbuckle, 1988; Brender, Olive, Felkner, Suarez, Hendricks et al., 2004; Brender, Olive, Felkner, Suarez, Marckwardt, et al., 2004; Croen et al. 2001; Dorsch et al., 1984) have reported statistically significant findings linking drinking water nitrate to neural tube defects. Brender, Olive, Felkner, Suarez, Hendricks, et al. (2004); Brender, Olive, Felkner, Suarez, Marckwardt, et al. (2004); Croen et al. (2001); and Huber et al. (2013) also compared the dietary intake of nitrate to health implications related to neural tube defects and found minimal or no effect on risk. These findings on the adverse health effects of nitrate exposure are significant to the users of private wells; however, because private well users are not required to test the water in their wells, it is difficult to identify the actual source of nitrate in order to mitigate the risk factors.

Elevated nitrate levels in drinking water can be a leading indicator of other human effects on private well water sources because private wells are more likely to have a higher concentration of contaminants that can adversely affect human health, especially that of women of child-bearing age. Manassaram et al. (2010) noted that private water systems have nitrate levels above the MCL because they are not regulated. For these reasons, pregnant women who are exposed to nitrate concentrations above the MCL in drinking water also might be exposing their unborn children to adverse health outcomes.

Weihe and Grandjean (2012) suggested that the health risks from in utero exposure to pollutants might not be immediately apparent until some years later. Precautionary approaches and preventive measures will help to reduce the risk of environmental exposure to chemicals that are known or suspected risk factors for developmental disabilities (Buczyńska & Tarkowski, 2005). On the other hand, maternal exposure to alcohol and smoking are other environmental factors that might contribute to the adverse health of pregnant women (Mateja, Nelson, Kroelinger, Ruzek, & Segal, 2012; Smedts et al., 2008). There is a need for a better understanding of the environmental etiology of birth outcomes that will help to guide public health policy and practice. Such awareness will educate private well owners about the adverse health effects of groundwater contaminants.

**Groundwater Quality**

Groundwater is a natural resource in Oklahoma and is a source of drinking water nationwide. Oklahomans who depend on groundwater use 21 main aquifers in the state as their major source of water (Fabian & Myers, 1990; Osborn & Hardy, 1999). Major and nonmajor aquifers serve Oklahoma’s water needs. Major aquifers yield more than 150 gallons/minute (Fabian & Myers, 1990; Osborn & Hardy, 1999); nonmajor aquifers can yield less than 150 gallons/minute (Johnson, 2008).

The presence of nitrate in groundwater is determined by many factors, such as anthropogenic, nature, and atmospheric nitrogen (Fabian & Myers, 1990; Osborn & Hardy, 1999). Major aquifers have been identified with anthropogenic water quality problems or concerns. Becker (2006) and the ODEQ (2010) identified private and domestic wells nitrate levels between 0.05 and 25 mg/L in water from shallow wells in Oklahoma. Most private wells in rural areas are shallow. The MCL for drinking water nitrate has been set at 10 mg/L by the USEPA. A nitrate concentration greater than 2 mg/L indicates anthropogenic sources (Mueller & Helsel, 1996), meaning that human activities such as fertilizer applications and animal waste could be contributing to elevated levels of nitrate concentration.

Elevated levels of nitrate have been identified more in antlers bedrock aquifers than in river alluvial aquifers (OWRB, 2013). Aquifers are sources of domestic water for most Oklahomans who depend on groundwater for their drinking water supplies. When contaminants are found in aquifers, the consequence can be health concerns for the communities that depend on them. For example, the OWRB (2013) noted that elevated concentrations of nitrate occur in shallow water, which can be a concern for domestic well users. Private well users should be provided with information about the aquifers or natural underground water storage that supplies and recharges their water wells. Well-informed stakeholders can make environmental decisions on how best to protect their individual wells' sustainability.

**Safe Drinking Water Act**

The goals of the SDWA (1974) are to ensure that U.S. groundwater is safe from contaminants and meets minimum standards for drinking water (as cited in USEPA, 2006). The USEPA's (2002, 2006) MCL for NO3-N is 10 mg/L for public drinking water to ensure human health; however, there is no requirement that private well owners monitor their individual wells for contaminants. Approximately 37 to 42 million residents of the United States are not on public water supplies and are not covered under the SDWA (Magdo et al., 2007), meaning that these residents might be exposed to environmental contaminants in their source water. Private well users are not protected under this law, so some rural residents in Oklahoma might be vulnerable to water-borne diseases and chemical contaminants such as nitrate. Environmental education tailored to private well owners, especially those who live in rural areas, could help stakeholders to make informed decisions that reflect good environmental stewardship.

It is the responsibility of the regulatory agencies in Oklahoma that are involved in the protection of Oklahoma's groundwater to set the standards. Oklahoma has groundwater standards located in OAC 785:45-7 (OWRB, 2011). Beneficial uses of the groundwater in the state are determined by levels of harmful biological, inorganic, and organic chemicals, including total dissolved solids (TDS). Groundwater with a mean concentration of TDS of less than 3,000 mg/L can be used for public and private water supplies. Groundwater with a mean concentration of TDS of greater than or equal to 3,000 mg/L can be used for agricultural and industrial purposes, municipal processes, and cooling water (OWRB, 2013). The significance of the levels of TDS cannot be overemphasized. For instance, public and private water sources with less than 3,000 mg/L of solids will need minimal treatment of their drinking water, water with solids in the range of 5,000 mg/L solids will have limited use, and water with greater than 10,000 mg/L mineral content is nonbeneficial for use because of its poor quality and need for further treatment (Smithee, 2009). For most Oklahomans on groundwater, obtaining information about the quality of the groundwater will help them to make decisions that will protect their water source.

**Geologic Formation and Ecology**

Oklahoma has 77 counties, with Osage being the largest of them. It is a diverse state that has 10 geologic formations spanning 70,000 square miles (Johnson, 2008; Perlman, 2013). The distance from north to south and from east to west is 482 miles and 230 miles, respectively. Oklahoma has an elevation of about 290 feet at its lowest point and 4,970 at the highest point (Johnson, 2008). This elevation is significant because of its impact on precipitation around the state.

Of the 1,629 public water systems in Oklahoma, 909 use groundwater as their primary source of water. These systems provide more than 734,553 Oklahomans with drinking water (Smithee, 2005). In addition to public water systems, many rural Oklahomans get their water from 44,435 private water wells registered with the OWRB that serve approximately 150,000 individuals statewide (Smithee, 2005). Informed private well users will be able to make informed decisions based upon available information.

**Physiographic Provinces**

Oklahoma is located within six major physiographic provinces that are differentiated based upon their geological formations (Ryder, 1996). These physiographic features affect evapotranspiration as well as the quantity and quality of precipitation that percolate and recharge Oklahoma's aquifers or groundwater (Ryder, 1996). The quality of groundwater is important because the majority of private well users depend on it as their only source of drinking water.

Exposure to N-nitroso compound, converted nitrogen species, found in various food items and drinking water might be of public health concern to consumers. Human beings also are exposed to transformed nitrogen species via the environment; this exposure can result in the formation of transformed nitrogen species endogenously (Brender, Olive, Felkner, Suarez, Marckwardt, et al., 2004; Croen et al., 2001). Griesenbeck et al. (2010) noted that these transformations had health implications in observed laboratory animals. Griesenbeck et al. studied the relationship between various maternal characteristics and the exposure to nitrogen species from dietary sources. They found that the exposure to nitrogen species varied demographically. However, Griesenbeck et al. concluded that targeted, focused, and stratified research is need to determine the risk between converted nitrogen species and the health implications of unborn children. Other researchers who have investigated the relationship between N-nitroso precursors associated health effects have reached the same conclusion (Huber et al., 2013; Smith, Hold, Tahara, & El-Omar, 2006; van Grinsven et al., 2006). Sources of nitrate must be identified because food and drinking water are possible sources of N-nitroso compounds. This type of clarity might help to inform private well owners about the various sources of nitrate in the environment.

Human beings are exposed to contaminants such as nitrate and nitrite via the environment. Gupta et al. (2008) noted that exposure to nitrate ingestion above the MCL has health implications. Some research has identified the health effects of drinking water nitrate on infants, but whether nitrate contributes to adverse health outcomes for adults remains controversial (Manassaram et al., 2010; Pawełczyk, 2012; Suvedi & Krueger, 2000). Karimzadeh et al. (2012) found that the intake of dietary nitrogen species (i.e., nitrate and nitrite) has the opposite health effect. The results identified an increased risk of lung cancer with meat consumption and a reduced of risk with fruit intake. Nitrate might be procarcinogen when combined with nitrogen compounds endogenously, which could be a precursor to animal cancer (McElroy et al., 2008; Mitacek et al., 2008; Tricker & Preussmann, 1991; Van Grinsven, Rabl, & de Kok, 2010), following the reduction of nitrate to nitrite with the help of enzymes in the saliva (Walker, 1990). Gupta et al. also indicated that nitrate is a controversial carcinogenic ion that needs further investigation. Other researchers have observed more effects, including miscarriages and diarrhea (S. Kim et al., 2012; Ostro, Roth, Malig, & Marty, 2009); hypothyroidism (Weinhold, 2010); and other health implications (Gupta et al., 2008). There is a potential health risk from nitrate and its derivatives, so private well owners should be made aware of how they could affect them.

Researchers also have provided evidence of the health effects of nitrate (nitrogen species) on populations exposed to nitrate concentrations above the MCL of 10 mg/L.

Nitrate derivatives might be mutagenic above the MCL. Gatseva and Argirova (2008) evaluated the health effects of nitrogen species on pregnant women and children based upon levels of iodide in the thyroid. Gatseva and Argirova found that the health impact on the women was significant; there was no impact on the children. Gatseva and Argirova showed that a nitrate concentration above the MCL could have adverse health impacts on vulnerable populations.

In another case, Weinhold (2010) noted a relationship between nitrate ingestion and thyroid cancer. On the contrary, Tulupov, Prikhod'ko, and Fomichenko (2001) found that nitrites, when combined with amines derivatives, are carcinogenic agents. Galaviz-Villa et al. (2010) reported that the potential negative health effects of nitrate can lead to problems such as dysfunction of the thyroid gland; however, Galaviz-Villa et al. also argued that nitrate in drinking water as a carcinogenic agent is inconclusive. Nitrate exposure could be a potential health risk to private well owners who consume drinking water containing a concentration of nitrate greater than the USEPA's (2012c) MCL of 10 mg/L.

Health implications based upon an association between nitrate and cancer have been inconclusive. Thorpe and Shirmohammadi (2005) explored a possible association between drinking water nitrates and herbicides among vulnerable populations for signs of cancer. Ward et al. (2005) studied colon cancer and neural tube defects, and they identified nitrogen species as a precursor for cancer that can impact the health of unborn infants. Ward et al. concluded that in-depth studies should be conducted before any policy changes on drinking water MCLs are made. Nitrate and nitrite might play a role in the etiology of cancer; the derivatives of nitrate have health implications (Tricker & Preussmann, 1991) that could include having an impact on the lymphatic system (Bogovski & Bogovski, 1981; Gulis, Czompolyova, & Cerhan, 2002; Mirvish, Weisenburger, Salmasi, & Kaplan, 1987). Nitrate exposure could be a potential health risk for cancer; therefore, private well owners should be made aware of the health risks related to groundwater nitrate exposure.

Anthropogenic changes in the quality of groundwater over the decades cannot be overemphasized, especially in rural areas. The growing population will increase their use of agricultural fertilizers to boost crop production; this use is the primary source of nitrate contamination in private wells. The rural population obtain their drinking water from private wells. Rogan and Brady (2009) noted that about 50,000 U.S. households rely on private wells as their water source. However, the quality of the water in these wells cannot be guaranteed because private wells are not regulated (USEPA, 2012c). States regulate well construction and control how much water is withdrawn from various aquifers, but individual wells are no longer monitored after construction unless they are for public use. Private well users are the custodians of their wells, so the quality of the water depends entirely on how well they maintain the wells. Vulnerable individuals in these households might be exposed to chemical contaminants because there is no testing requirement to check the water quality.

## Nitrates and Human Health

Human beings consume more nitrate from food than from air and drinking water combined (World Health Organization [WHO], 2007).The public health challenge that nitrate poses cannot be overemphasized, especially among those rural residents in Oklahoma who depend on private wells as their source water. The endogenous metabolism of nitrate coverts it to nitrite, which is the reactive form of nitrogen in human beings, especially among infants (Galaviz-Villa et al., 2010; Gupta et al., 2008; Manassaram et al., 2010; Tulupov et al., 2001; Vitoria, Brines, Morales, & Llopis, 1991; WHO, 2007). For private well users, the presence of nitrate above the USEPA's (2012b) MCL of 10 mg/L might present some health concerns, especially if infants are in the household. Homeowners must be informed about the hazard of nitrate exposure and the health implications for methemoglobinemia.

Nitrogen species (nitrate and nitrite) occurs naturally in the environment. Sources of nitrate can be either point sources or nonpoint sources. Human beings assimilate nitrate into the body; however, the problem is not the nitrate, but the nitrite that forms when nitrate converts to nitrite. Manassaram et al. (2006) concluded that except for methemoglobinemia, researchers have not provided enough data on the health implications of nitrate on unborn children. Gulis et al. (2002), Tulupov et al. (2001), Ward et al. (2005), and the WHO (2007) asserted that nitrate is a public health concern and supported Manassaram et al.'s conclusion about the health effects of nitrate. Public health communities must educate private well users to make them aware of the health effects.

Nitrate is a common contaminant in Oklahoma resulting from fertilizer application, especially among rural residents on private wells. Zeman et al. (2011) examined Iowa private well users' drinking water below the MCL of 10 mg/L nitrate-nitrogen (nitrate-N). Zeman et al. found adverse health implications in nitrate concentration below the MCL. They also observed that nitrate serves dual purposes. For example, even though nitrate is essential for human health (Archer, 2002), a concentration of nitrate above an MCL of 10 mg/L poses a threat to human health (Avery & L’hirondel, 2003). There is a need to develop a program that will educate private well owners on the complexities of nitrate in the environment.

Stakeholders such as the U. S. Department of Human Services (2010) and the American Academy of Pediatrics (as cited in Rogan & Brady, 2009) have advocated for well testing as a way to mitigate children’s exposure to nitrate. Hoppe et al. (2011) analyzed the results of private well testing from real estate transactions in Oregon and found that the state’s counties had the largest number of wells in Oregon containing elevated levels of nitrate. Similarly, in an analysis of available nitrate data from private wells in individual households tested between 1999 and 2008, the ODEQ (2010) found that private wells could have nitrate concentrations exceeding the USEPA’s (2012c) standard. There are potential health risks to exposure of high nitrate levels above the MCL of 10 mg/L (Hoppe et al., 2011).

No federal law or program monitors the quality of private wells, unlike the SDWA (1974, as cited in USEPA, 2006), which monitors public water systems. Under the SDWA, the USEPA (2012c) sets MCLs for drinking water supplied through public water systems. Yet, even though approximately 45 million people in the U.S. population rely on groundwater from private wells, the quality of this water cannot be guaranteed (Hoppe et al., 2011). Private wells are not regulated, so for Oklahoma private well users, programs that could bring awareness and information about the issues of water contaminants and the health effects of nitrate in groundwater will be beneficial to the community and public health.

## Summary and Transition

In Chapter 2, I reviewed the relevant literature on nitrate and community perceptions among the stakeholders. Great numbers of the U.S. population rely on private wells for household needs, but the quality of this water cannot be guaranteed (Hoppe et al., 2011). Concern about the concentration of nitrate in drinking water might not be well understood, especially among private well users. Hexemer et al. (2008) noted that the lack of education about proper well maintenance and the inconvenience of spending time on well maintenance by private well users are key barriers to private well water stewardship. Furthermore, private wells are unregulated, so the magnitude of potential contaminants might not be known and might present a public health challenge to private well users. The review of the literature showed that researchers have conducted few empirical studies evaluating community members’ perceptions of collaboration in and barriers to the management of health threats in private well water sources (Jones et al., 2006). Developing an understanding of this issue from the perspectives of private well owners, who might have different levels of interest, is the first step toward private well water sustainability. By conducting a survey, I gained community members’ perceptions of community collaboration as a method to achieve sustainability.

In Chapter 3, I describe the study design, target population, study sample, setting, data collection and analysis protocols, and ethical treatment of the participants.

# Chapter 3: Research Method

## Introduction

The purpose of this quantitative study was to examine data on nitrate concentration and cases of congenital cardiac defects in Oklahoma. It was my intention to describe and understand community members' perceptions of community collaboration to achieve groundwater sustainability and the perceived barriers to obtaining community collaboration among private well users in Oklahoma. I also wanted to determine whether these community members' perceptions of community collaboration and barriers to achievement varied by demographic variables. Therefore I used the Sustainability and Community Collaboration Survey.

I explored community members' perceptions of community collaboration as a method of sustaining private wells. I wanted to know whether certain demographic or background variables (i.e., gender, age, home ownership, education, length of residence in the area, use of water source for drinking water) were related to community members' perceptions of community collaboration or barriers to community collaboration. I did not look for causal relationships or associations because of limitations in the existing data, lack of data, or other confounders; instead, I generated data for future research. In this chapter, I explain the methods, including the research design, target population, study sample, instrumentation, data collection and analysis protocols, and steps to protect the participants' rights.

## Research Design and Rationale

I employed a quantitative, cross-sectional, nonexperimental design to describe the community members' perceptions of community collaboration to achieve groundwater sustainability and any perceived barriers to gaining such collaboration. I also explored the relationship between and among these perceptions and the demographic characteristics of the sample. The cross-sectional design was appropriate for this study because of its descriptive and exploratory nature (Creswell, 2009). This design allowed me to spend my limited time and funding to gather, analyze, and interpret the data from the sample. I also found this design helpful in assessing the relationship between and among the variables of interest, thus facilitating the generation of hypotheses (Page et al., 1995). In addition, because the design required fewer participants to detect an association, it gave me the flexibility to explore numerous health outcomes and related risk factors at the same time. An advantage of cross-sectional studies is that the data can be collected all at once and there is no need for follow-up activities (Creswell, 2009; Page et al., 1995).

I used a survey to assess community perceptions of the collaboration and barriers to attain groundwater sustainability among private well owners. Households that depend on private well water as their only source of drinking water are at risk of exposure to contaminants such as nitrate (USEPA, 2012c). This exposure is more likely to occur in private wells because they are unregulated in most areas of Oklahoma. This design helped me to collect information from the respondents pertaining to their perceptions of water quality and alternative water sources because the design is strongly rooted in theory.

When the temporal nature of a phenomenon is not clear, it also is likely that intervening events will confound a follow-up study (Rindfleisch et al., 2008). The households in this case were able to provide the required information at the time of the survey, making attrition, as in longitudinal studies, unlikely (Rindfleisch et al., 2008). This was a hypothesis-generating study, so I did not make any association between levels of nitrate concentration and health outcomes; rather, I focused on rural residents' perceptions of their groundwater quality.

The primary purpose of quantitative research is to evaluate the relationship between and among IVs and DVs. In quantitative studies, researchers focus on descriptive analysis to describe a one-time phenomenon by which the participants are measured (Babbie, 2007; Trochim & Donnelly, 2007). A quantitative methodology was suitable for this study because it allowed me to use closed-ended survey questions to gather information for future analysis and interpretation. Qualitative researchers prefer the use of open-ended questions that allow the participants to express their own views. In this study, I gathered information and data about community members' perceptions of community collaboration to achieve groundwater sustainability and any perceived barriers to obtain such collaboration using a quantitative approach. I used the data to explore the relationship between these perceptions and the demographic characteristics of the sample.

Qualitative research is usually exploratory, so researchers focus on qualitative measures or observations of natural phenomena (Lofland & Lofland, 1995). Researchers interested in mixed methods or multistage studies have to combine qualitative and quantitative designs (Babbie, 2007; Creswell, 2009; Trochim & Donnelly, 2007). Qualitative research did not provide the depth of uniformity of responses required for this type of research because of the use of open-ended questions, which might sometimes require interviewing the participants. For these reasons, neither a qualitative design nor a mixed methods design was appropriate.

## Setting and Sample

### Setting

The setting was in the state of Oklahoma. In this study, I delineated the characteristics of the state (e.g., population, race distribution, drinking water sources, number of private well users, nitrate level, and incidence of congenital cardiac defects). I concentrated on households in Oklahoma that use private wells as their only source of water. I used random sampling to select representative households. This sampling method allowed me to choose a sample from a given target population; each household had an equal opportunity of being selected (Thompson, 2002). The target population were all households in Oklahoma County, which comprises Edmond, Midwest City, Del-city, Bethany, Arcadia, and Moore, with a total population of 718,633 who use private wells.

I obtained a list of addresses of private well owners from the OWRB. I addressed the survey to the resident of each household where the private well was located. I assigned a nonskipping and unique numerical value to each household in this list. Then, I selected sample households using computer-generated random numbers. I used Microsoft Excel’s RAND function to generate random numbers. I then assigned one random number to each address where a private well was located using a function called INDEX.

**Sample Size**

I conducted the power analysis and sample size calculation using G*Power v.3.1.3 for Windows. I modeled the data using multiple linear regression with 10 predictor variables, 95% power, and 5% significance level to detect medium effect size (effect size $f^2 = 0.15$). A sample size of 172 was required. I used power analysis and sample calculation method to generate the needed sample size (Erdfelder, Faul, & Buchner, 1996). Following are the input provided to G*Power and the output generated by the software:

***F* tests -** Linear multiple regression: Fixed model, $R^2$ increase

**Analysis**: A priori: Compute required sample size

**Input:** Effect size $f^2 = 0.15$

$\alpha$ err prob = 0.05

Power (1-$\beta$ err prob) = 0.95

Number of tested predictors = 10

Total number of predictors = 10

**Output:** Noncentrality parameter $\lambda = 25.8000000$

Critical F = 1.8899310

Numerator *df* = 10

Denominator *df* = 16

Total sample size = 172

Actual power = 0.95

Figure 1 shows the relationship between power and size at different levels of effective size using the same input parameters as in sample size calculation.

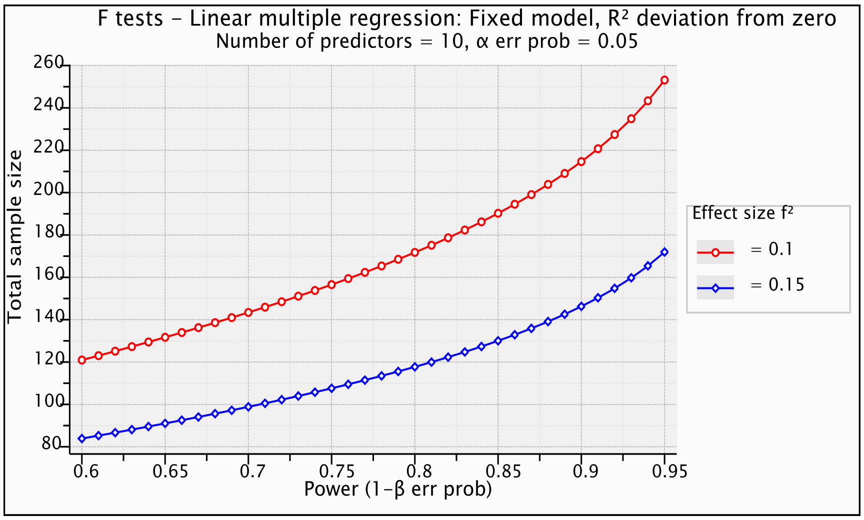



*Figure 1.* Power versus sample size at different effect sizes.

## Instrumentation

I used a self-reported survey instrument to collect the data from private well owners. I sought and received permission to modify the original instrument, which was been developed by Dr. David Mulhearn of the University of Southern Maine, Lewiston-Auburn College (see Appendices C & D). The survey is divided into three sections. Section A comprises definitions of sustainable water systems, restriction of use, and community collaboration. I also used Section A to collect information about the participants (e.g., age, gender, education) and background information (e.g., ownership of property, length of stay, etc.) via multiple-choice questions. Section B includes a six-item scale assessing the participants' perceptions of community collaboration to achieve groundwater sustainability. Each item in this section is answered using a 5-point Likert scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). Section C holds a five-item scale assessing the participants' perceptions of the barriers to community collaboration. Like the items in Section B, each item in Section C is answered using a 5-point Likert scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). In addition, Section C contains one descriptive type and open-text field response question about any other barriers to community collaboration not covered in the five-item scale.

I stored the answers to the multiple-choice questions in Section A as categorical dummy variables and the answers with numerical values (e.g., age) as categorical variables. I aggregated the scores from the six items in Section B to calculate the total perception score, which had a minimum value of 6 and a maximum value of 30. A higher total perception score indicated that the participants had a more positive perception of community collaboration in achieving drinking water sustainability. However, participants with a lower total perception score placed small value on community collaboration to achieve water sustainability. Likewise, I aggregated the responses from Section C to calculate a total barrier score that ranged from 5 to 25. A higher total barrier score indicated perceptions of stronger barriers to community collaboration. A lower total barrier score indicated perceptions of few barriers to community collaboration to develop sustainable water sources.

I assigned each completed survey a numeric identifier. I then entered and stored the data from the completed surveys on an Excel spreadsheet. These raw data are available electronically to my Walden University committee members upon request. I will shred all paper copies of the survey, and I will store all electronic copies of the raw data for 5 years before destroying them.

I modified the original survey primarily by removing questions about surface and public water sources and replacing them with questions about private wells. I included additional questions that addressed this study's RQs specifically. The extra questions in this case were within the general environment categories, which was where most of the variance occurred. I added some questions not in the original survey to identify areas relevant to my research.

Modifying the original survey was necessary for the purposes of this study, so the reliability of the modified instrument could have become a concern. The reliability coefficient of the original instrument was > .70 (Mulhearn, 2007). To ensure the internal validity of the data based upon the modified survey, I conducted a pilot test of the survey with 20 participants, all of whom are residents of Oklahoma. I excluded any participant from the main study in the sample who completed the pilot survey. I assessed the internal consistency and reliability of the two composite scores via Cronbach's alpha for a coefficient .70 or more. The reliability coefficient of the original instrument was > .70 (Mulhearn, 2007).

## Pilot Study

As mentioned, I pilot tested the final version of the survey with 20 participants to ensure that the questions were clear and reflected the RQs, and served as a way to determine the internal consistency of the questionnaire. If needed, I added or removed questions to improve the validity and reliability of the survey based upon the performance, suggestions, and recommendations of the pilot study participants.

**Dependent Variables**

The total perception score and the total barrier score were the dependent variables, or DVs. Both variables were continuous.

**Independent Variables**

This study had 10 independent variables, or IVs: age, sex, education, homeownership, length of stay in this area, distance from animal waste sites or agricultural property, use of private well, source of drinking water, membership in homeowners/landowners association, and desire to join homeowners/landowners association. Age was categorized as 18 to 34 years 35 to 54 years, 55 to 65 years, 65 to 74 years, and 75 to 85 years. Length of stay (LOS) in the county was categorized as all my life, Greater than 10 years, 5 to 9 years, and less than 5 years. Distance from animal waste sites or agricultural property was categorized as less than 5 miles, 5 to less than 10 miles, 10 to less than 15 miles, and more than 15 miles. Sex was categorized as male (sex = 1) and female (sex = 2). The independent variables (IVs) were categorized because some individuals responded better to age and residence categories rather than by offering specific responses. I grouped education as no high school diploma (education = 1), high school diploma (education = 2), some college courses (education = 3), bachelor's degree (education = 4) or graduate degree (education = 5). Homeownership was categorized as yes (own = 1) or no (own = 2). Use of private well was categorized as irrigation (use = 1), industrial use (use = 2), domestic use (use = 3) or agricultural use (use = 4). Source of drinking water was categorized as public water supply (source = 1), private well (source = 2), bottled water (source = 3), and do not know (source = 4). Membership in homeowners/landowners association was categorized as yes (membership = 1) or no (membership = 2). Similarly, desire to join homeowners/landowners association was categorized as yes (join = 1) or no (join = 2; see Table 1).

Table 1

*Descriptions of Important Study-Related Variables*

| Variable | Description | Type of variable |
|---|---|---|
| DVs | | |
| Total perception score | Total perception score calculated from responses to questions in Section B (values between 6 and 30) | Continuous |
| Total barrier score | Total perception score calculated from responses to questions in Section C (values between 5 and 25) | Continuous |
| IV | | |
| Age | Age of participant<br>18-34 yrs<br>35-54 yrs<br>55-65 yrs<br>65-74 yrs<br>75-85 yrs | Categorical |
| LOS in county | How long have you lived in your county?<br>All my life<br>> 10 yr<br>5-9 yr<br>< 5 yr | Categorical |
| Distance | Distance from animal waste sites or agricultural property<br>< 5 miles<br>> 5 to < 10 miles<br>> 10 to < 15 miles<br>> 15 miles | Categorical |
| Sex | Gender of participant<br>Male: Sex = 1<br>Female: Sex = 2 | Categorical (binomial) |
| Education | Education of participant<br>No high school diploma: Education = 1<br>High school diploma: Education = 2<br>Some college courses: Education = 3<br>Bachelor's degree: Education = 4<br>Graduate degree: Education = 5 | Categorical |
| Own | Homeownership<br>Yes: Own = 1<br>No: Own = 2 | Categorical (binomial) |

Table 1 Cont'd

| Variable | Description | Type of variable |
|---|---|---|
| Use | Use of private well<br>Irrigation: Use = 1<br>Industrial: Use = 2<br>Domestic: Use = 3<br>Agricultural: Use = 4 | Categorical |
| Source | Source of drinking water<br>Public water supply: Source = 1<br>Private well: Source = 2<br>Bottled water: Source = 3 | Categorical |
| Membership | Membership with homeowners/landowners association<br>Yes: Membership = 1<br>No: Membership = 2 | Categorical (binomial) |
| Join | Desire to join homeowners/landowners association<br>Yes: Join = 1<br>No: Join = 2 | Categorical (binomial) |

## Survey Distribution

I conducted a mailed survey of private drinking water well owners in Oklahoma counties. The mailing list comprised 4,000 randomly selected addresses of private well owners registered with the OWRB. I selected 1,310 addresses from this list and then sent the survey initially to 600 residents to obtain their perceptions of private drinking water well sustainability using Dillman et al.'s (1995) four-stage mail survey methodology. Included with the survey were a cover letter and a self-addressed, stamped return envelope. After 15 days, I sent a reminder to all nonresponders. Following the reminder letter, I sent another package to the next 710 residents who were not on the initial mailing list and who had not yet received the survey among the 1,310 selected addresses. Finally, I analyzed the total number of responses using SAS v.9.2 for Windows.

## Data Collection and Analysis Plan

I mailed the survey package to each household randomly selected to be in the sample. To be eligible to participate in the study, a household had to (a) be inside the administrative boundaries of Oklahoma, and (b) have a private well on the property. Any household that failed to complete the survey, was located outside of Oklahoma's state boundary, did not have a private well on the property, or wished to withdraw early from the study was excluded from the final analysis.

I completed all statistical analyses using SAS v.9.2 for Windows. Initial analysis included descriptive statistics of the demographic characteristics of the sample and the distribution of the background variables. I reported the descriptive statistics of the categorical variables (sex, education, homeownership, use of private well, source of drinking water, membership in homeowners/landowners association, and desire to join homeowners/landowners association) as proportions or percentages. Similarly, I reported descriptive statistics of the continuous variables (total perception score, total barrier score, age, length of stay in the area, and distance from animal waste sites or agricultural property) as means and standard deviations. Statistical significance of the relationship between the DVs and the IVs was tested at the 5% significance level.

## Research Questions

The study was guided by two RQs and hypotheses:

1. What is the relationship between the community perceptions of stakeholders' collaboration and the demographic characteristics of the study sample (i.e., age, gender, education, homeownership, length of stay in the area, distance from animal waste sites or agricultural property, use of private well, source of drinking water, membership in homeowners/landowners association, and desire to join homeowners/landowners association)?

$H_{01}$: Community perceptions are not affected by any demographic factors of the sample (i.e., age, gender, education, homeownership, length of stay in the area, distance from animal waste sites or agricultural property, use of private well, source of drinking water, membership in homeowners/landowners association, and desire to join homeowners/landowners association).

$H_{a1}$: Community perceptions are affected by at least one of the demographic factors of the sample (i.e., age, gender, education, homeownership, length of stay in the area, distance from animal waste sites or agricultural property, use of private well, source of drinking water, membership in homeowners/landowners association, and desire to join homeowners/landowners association).

2. What is the relationship between community barriers to stakeholders' collaboration and the demographic characteristics of the study sample (i.e., age, gender, education, homeownership, length of stay in the area, distance from animal waste sites or agricultural property, use of private well, source of drinking water, membership in homeowners/landowners association, and desire to join homeowners/landowners association)?

$H_{02}$: Community barriers to stakeholders' collaboration are not affected by any demographic factors of the sample (i.e., age, gender, education, homeownership, length of stay in the area, distance from animal waste sites or agricultural property, use of private well, source of drinking water, membership in homeowners/landowners association, and desire to join homeowners/landowners association).

$H_{a2}$: Community barriers to stakeholders' collaboration are affected by at least one of the demographic factors of the sample (i.e., age, gender, education, homeownership, length of stay in the area, distance from animal waste sites or agricultural property, use of private well, source of drinking water, membership in homeowners/landowners association, and desire to join homeowners/landowners association).

To address each RQ, I used simple and multivariate linear regression models. I assessed the relationship between total perception score and each IV using simple linear regression. I then built a multivariate linear regression model that contained age, sex, education, homeownership, length of stay in this area, distance from animal waste sites or agricultural property, use of private well, source of drinking water, membership in homeowners/landowners association, and desire to join homeowners/landowners association as the IVs (explanatory variables), and total perception score as the DV (outcome variable). Results of this multiple linear regression model provided the adjusted effect of each IV to determine the total perception score.

Similarly, I assessed the relationship between total barrier score and each IV using simple linear regression. I then built a multiple linear regression model to assess the adjusted effect of each IV on the total barrier score. Statistical significance of the relationship between the DV and the IVs was tested at the 5% significance level.

## Justification of Analysis

Multiple linear regression is a mathematical technique used to model the relationship between continuous variable types of IVs and numerous IVs. Unlike a simple linear regression, in which the model uses a single predictor variable, multiple linear regression incorporates a different mix of continuous as well as categorical (discrete) IVs (Glantz & Slinker, 2000; Kleinbaum, Kupper, Muller, & Nizam, 1997). This model helped me to determine not only which predictors (IVs) were important and their effect size but also the structure by which these multiple predictors simultaneously associated with the DV.

I used this model to determine whether the multiple predictors that influenced the DV did so independently or by interacting with each other (Slinker, 1998). However, to consider the results of this linear regression model accurate and valid, I needed to satisfy the assumptions of (a) linearity of a relationship between and the DV and IVs, (b) independence of the error terms, (c) constant variance of error terms, and (d) normal distribution of error terms. In addition, I assessed the correlation between and among different IVs because an association between two or more IVs could have affected the results of the study (Bryan & Stanton, 2008).

## Ethical Considerations

I did not collect any personal information (e.g., name, phone number, Social Security number, etc.) from any participants. I assigned a unique identifier to each participant during data collection to avoid duplicate records. I transferred all of the data collected through the paper survey to a computer data set and then stored them in my password-protected personal computer, restricting access to any external users. I then shredded and destroyed all paper documentation. I followed strict privacy guidelines during the data collection, analysis, interpretation, and dissemination phases of the study. I obtained approval from Walden University’s Institutional Review Board (IRB approval

#05-15-14-0123445) prior to conducting any part of this study. I reported all results at the aggregated or group level as well as any relevant or substantive changes in the study protocol to the IRB.

## Summary and Transition

In this chapter, I provided a description of the methodology, including the research design and rationale, methodology, target population, setting, and sample, as well as information about the pilot study, instrumentation, data collection and analysis protocols, and ethical considerations. The study results and interpretation of those results comprise an integral part of Chapter 4. The data analysis described in Chapter 4 also provides information on nitrate concentrations and the prevalence of congenital cardiac defects, as well as differences in the opinions and perceptions of a sample of private well users. Simple and multivariate linear regression models were used to test the hypotheses.

# Chapter 4: Results

## Introduction

The purpose of this study was to examine data describing nitrate concentration and cases of congenital cardiac defects. I explored community members’ perceptions of community collaboration as way of sustaining private water wells. I determined whether demographic variables (i.e., age, gender, education, homeownership, length of stay in the area, distance from animal waste sites or agricultural property, use of private well, source of drinking water, membership in homeowners/landowners association, and desire to join homeowners/landowners association) influenced individual perceptions of how communities could collaborate to mitigate health threats in private well water sources or whether the variables revealed barriers to such community collaboration that needed to be removed.

I did not determine causal relationships or associations because of data limitations or confounders. As such, the study can serve only as a platform to generate hypotheses for future research. I used a quantitative, nonexperimental design to (a) describe the community members’ perceptions about achieving groundwater (private well) sustainability, (b) identify any perceived barriers to collaborating to mitigate health threats, and (c) explore the relationship between these perceptions and the demographic characteristics of the sample.

In this chapter, I describe the methodology, including the research design and rationale, methodology, target population, setting, and sample, and I provide information about the pilot study, instrumentation, data collection and analysis, and ethical considerations. Chapter 4 also presents the results of this quantitative, cross-sectional, nonexperimental study. Simple and multivariate linear regression models were used to test the hypotheses.

## Research Questions and Hypotheses

The study was guided by two RQs and hypotheses:

1. What is the relationship between the community perceptions of stakeholders' collaboration and series of demographic characteristics of the study sample?

$H_{01}$: Community perceptions are not affected by any demographic factors of the study sample.

$H_{a1}$: Community perceptions are affected by at least one of the demographic factors of the study sample.

2. What is the relationship between community barriers to stakeholders' collaboration and series of demographic characteristics of the study sample?

$H_{02}$: Community barriers to stakeholders' collaboration are not affected by any demographic factors of the sample.

$H_{a2}$: Community barriers to stakeholders' collaboration are affected by at least one of the demographic factors of the sample.

## Descriptive Statistics

The final sample provided responses from 244 households, with 175 male (72.6%) and 66 female (27.4%) respondents. As mentioned, 244 surveys were returned, 231 of which were completed in full. Three respondents did not specify either gender. For some computations in this study, analysis was based upon the number of respondents who answered particular questions. It was not totally based upon either the 244 overall respondents or the 231 participants who completed all of the questions on the survey. Regression analysis used 231 completed questionnaires. I had wanted to capture the opinions of the 244 respondents who returned the questionnaire on every question answered collectively, irrespective of the fact that the survey was not answered completely. For the statistical analysis, I used *t* test (for binomial IVs) and ANOVA (for multinomial IVs) to assess whether differences in mean total perception scores were significant across different levels of IVs.

The independent variables (IVs) were categorized because some individuals responded better to age and residence categories rather than by offering specific responses. Along the same line of reasoning, the data were analyzed based upon those categories and groupings of the variables. More than 35.7% ($n$ = 87) of respondents were between the ages of 55 and 65 years, followed by 29.1% ($n$ = 71) between the ages of 35 and 54 years. Almost 28% ($n$ = 68) of respondents were 65 years and older, and 7.4% ($n$ = 18) of respondents were between the ages of 18 and 34 years (see Table 2). Most respondents (71.1%, $n$ = 172) had either a bachelor's degree or a graduate degree, 21.5% ($n$ = 52) had completed some college courses, and 7.4% ($n$ = 18) had high school or lower education. More than 93% ($n$ = 224) of respondents owned their residences, and 85.2% ($n$ = 208) had lived in their respective counties for either more than 10 years or all of their lives. Of the whole sample, 62.6% ($n$ = 152) indicated living within 5 miles of an animal waste site or farmland, 23% ($n$ = 56) lived between 5 and 10 miles from an animal waste site or farmland, and 14.4% ($n$ = 35) lived more than 10 miles from an animal waste site or farmland.

Almost 80.5% ($n$ = 194) of the respondents used private wells for irrigation and 85.1% ($n$ = 205) used them for domestic use. A total of 36.6% ($n$ = 89) used bottled water for drinking; 84.4% ($n$ = 205) used private or domestic wells for drinking; 43% of households used both private or domestic well and bottle water for drinking; and 15.2% ($n$ = 37) used public water supplies (i.e., community wells, surface water, or community wells and surface water). A total of 38.5% ($n$ = 94) of respondents were member of homeowners associations, and 48.1% ($n$ = 116) wanted to join homeowners associations.

Table 2

*Distribution of Study Sample*

| IVs | | Categorical/Categorical binomial | *n* (%) |
|---|---|---|---|
| Use of private Well | Irrigation use | No | 47 (19.5%) |
| | | Yes | 194 (80.5%) |
| | Domestic use of water | No | 36 (14.94%) |
| | | Yes | 205 (85.06%) |
| | Other use | No | 231 (95.85%) |
| | | Yes | 10 (4.15%) |
| Source of drinking water | Community well | No | 233 (95.88%) |
| | | Yes | 10 (4.12%) |
| | Surface water | No | 232 (95.47%) |
| | | Yes | 11 (4.53%) |
| | Community well or surface water | No | 225 (92.59%) |
| | | Yes | 18 (7.41%) |
| | Private well | No | 38 (15.64%) |
| | | Yes | 205 (84.36%) |
| | Bottled water | No | 154 (63.37%) |
| | | Yes | 89 (36.63%) |
| Age | | 18-34 yr | 18 (7.38%) |
| | | 35-54 yr | 71 (29.1%) |
| | | 55-65 yr | 87 (35.66%) |
| | | 65-74 yr | 47 (19.26%) |
| | | 75-85 yr | 21 (8.61%) |
| Gender | | Female | 66 (27.39%) |
| | | Male | 175 (72.61%) |
| Education | | High school diploma or lower | 18 (7.44%) |

| IVs | Categorical/Categorical binomial | *n* (%) |
|---|---|---|
| | Some college courses | 52 (21.49%) |
| | Bachelor’s degree | 76 (31.4%) |
| | | Table 2 Cont’d |
| | Graduate degree | 96 (39.67%) |
| Own a residence | No | 16 (6.67%) |
| | Yes | 224 (93.33%) |
| LOS in county | All my life | 74 (30.33%) |
| | > 10 yr | 134 (54.92%) |
| | 5-9 yr | 23 (9.43%) |
| | < 5 yr | 13 (5.33%) |
| Distance from animal waste site or farmland | < 5 miles | 152 (62.55%) |
| | > 5 to < 10 miles | 56 (23.05%) |
| | > 10 to < 15 miles | 22 (9.05%) |
| | > 15 miles | 13 (5.35%) |
| Member of homeowners association | No | 150 (61.48%) |
| | Yes | 94 (38.52%) |
| Consider joining homeowners association | No | 125 (51.87%) |
| | Yes | 116 (48.13%) |

Table 3 shows the distribution of total perception score by various IVs in this study. I used the *t* test (for binomial IVs) and ANOVA (for multinomial IVs) to assess whether the different in mean total perception score was significantly different across different levels of IVs. Results showed that the mean total perception scores were significantly different for education, distance of residence from an animal waste site or farmland, use of bottled water for drinking, and use of private well for irrigation ($p$ value < .05). Mean total perception score was not different between groups for other IVs. The mean total perception score was 16 for respondents with “no high school diploma” and more than 19.53 for respondents with “bachelor’s or graduate degree.” Similarly, mean total perception score was about 16.46 for respondents living more than 15 miles from an animal waste site or farmland. However, mean total perception score was more than 19.30 for respondents living within 15 miles of an animal waste site or farmland.

Respondents who used bottled water for drinking had a higher mean total perception score (19.64) than respondents who did not drink bottled water (18.85). Similarly, respondents who used private wells for irrigation had a higher mean total perception score (19.50) than respondents who did use private wells for irrigation (17.79).

Table 3

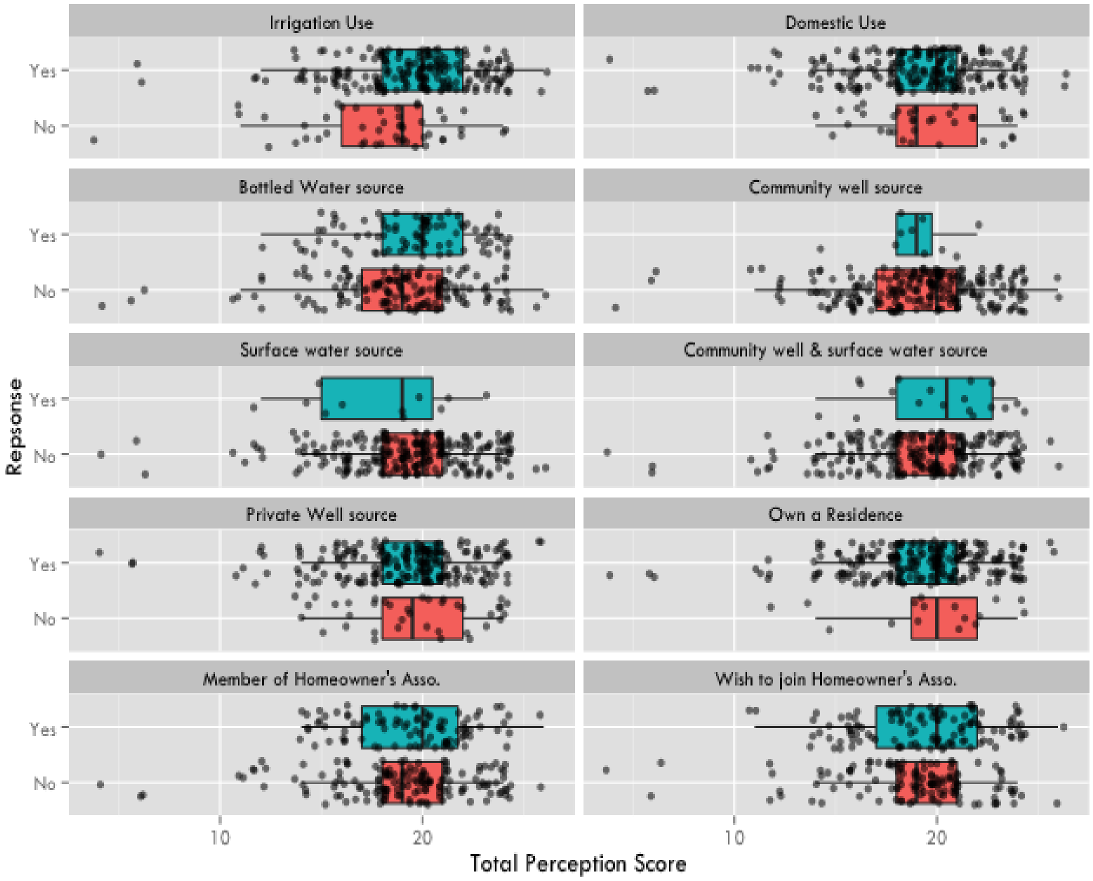
*Distribution of Total Perception Score*

| IVs | | Category | Total perception score, *M* (min- max) | Statistic | *p* value |
|---|---|---|---|---|---|
| Use of private Well | Irrigation use | No | 17.79 (4 - 24) | -2.893 | .005* |
| | | Yes | 19.5 (6 - 26) | | |
| | Domestic use of water | No | 19.64 (14 - 24) | 1.019 | .313 |
| | | Yes | 19.08 (4 - 26) | | |
| | Other use | No | 19.2 (4 - 26) | 1.02 | .331 |
| | | Yes | 18.3 (12 - 21) | | |
| Source of drinking water | Community well | No | 19.15 (4 - 26) | 0.495 | .63 |
| | | Yes | 18.8 (14 - 22) | | |
| | Surface water | No | 19.21 (4 - 26) | 1.374 | .197 |
| | | Yes | 17.73 (12 - 23) | | |
| | Community well or surface water | No | 19.07 (4 - 26) | -1.288 | .212 |
| | | Yes | 20.06 (14 - 24) | | |
| | Private well | No | 19.53 (14 - 24) | 0.805 | .424 |
| | | Yes | 19.07 (4 - 26) | | |
| | Bottled water | No | 18.85 (4 - 26) | -1.878 | .062 |
| | | Yes | 19.64 (12 - 24) | | |
| Age | | 18-34 yr | 19.94 (16 - 24) | 1.543 | .19 |
| | | 35-54 yr | 19.46 (12 - 24) | | |
| | | 55-65 yr | 19.37 (11 - 26) | | |
| | | 65-74 yr | 18.34 (4 - 24) | | |
| | | 75-85 yr | 18.29 (6 - 24) | | |
| Gender | | Female | 19.44 (14 - 24) | 0.961 | .338 |
| | | Male | 19.02 (4 - 26) | | |
| Education | | High school diploma | 19.11 (12 - 26) | 3.66 | .013* |
| | | Some college courses | 17.83 (6 - 24) | | |
| | | Bachelor’s degree | 19.71 (12 - 26) | | |
| | | Graduate degree | 19.4 (4 - 24) | | |
| Own a residence | | No | 19.56 (12 - 24) | 0.437 | .668 |
| | | Yes | 19.17 (4 - 26) | | |
| LOS in county | | All my life | 18.74 (6 - 26) | 0.758 | .519 |
| | | > 10 yr | 19.32 (4 - 24) | | |
| | | 5-9 yr | 19.7 (16 - 24) | | |
| | | < 5 yr | 18.69 (15 - 23) | | |

| IVs | Category | Total perception score, *M* (min- max) | Statistic | *p* value |
|---|---|---|---|---|
| Distance from animal waste site or farmland | <5 miles | 19.03 (4 - 26) | 4.112 | .007* |
| | > 5 to < 10 miles | 19.8 (12 - 24) | | Table 3 |
| | > 10 to < 15 miles | 19.95 (14 - 24) | | Cont'd |
| | > 15 miles | 16.46 (6 - 22) | | |
| Member of homeowners association | No | 18.97 (4 - 26) | -1.078 | .282 |
| | Yes | 19.43 (14 - 26) | | |
| Consider joining homeowners association | No | 18.86 (4 - 26) | -1.394 | .165 |
| | Yes | 19.46 (11 - 26) | | |

*Note*. **p* value < .05

Figure 2 shows the distribution of total perfection score by IV using boxplots to depict how total perception scores were distributed based upon the number of responses. Total perception scores were normally distributed when compared by different categorical independent variable (IVs). The *t* test was appropriate for the comparison of mean total perception score in different categories. Boxplots were used to describe the continuous variables. As shown in Table 1, total perception score was a continuous variable. In this figure, the total perception score was normally distributed by different independent variables (IVs). Overall, the boxplot shows the distribution of scores by categorical variables.



Irrigation Use
Domestic Use
Bottled Water source
Community well source
Surface water source
Community well & surface water source
Private Well source
Own a Residence
Member of Homeowner's Asso.
Wish to join Homeowner's Asso.
Yes
No
Repsonse
10
20
Total Perception Score

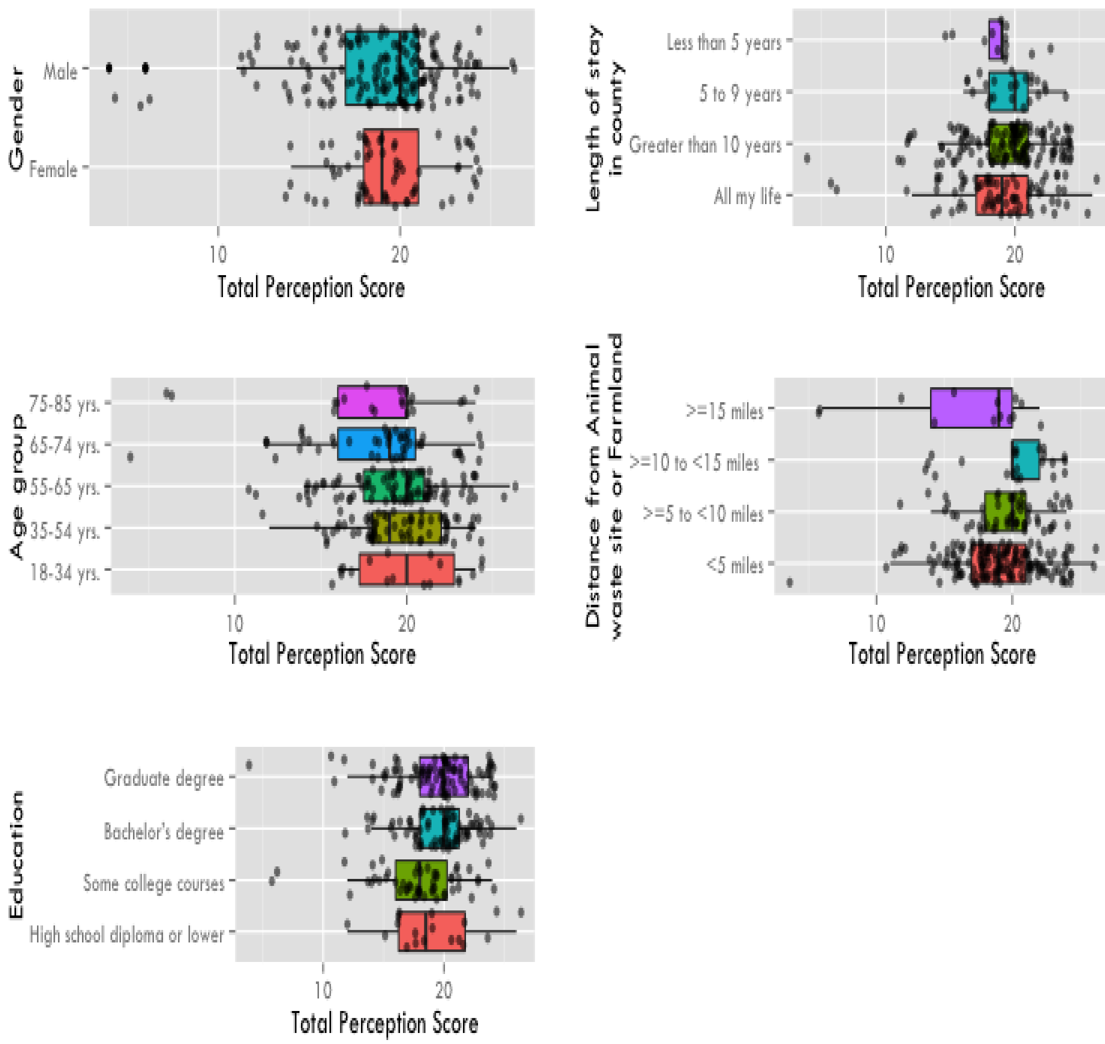



*Figure 2.* Distribution of total perception score by IV.

Distribution of the total barrier score for each IV is shown in Table 4. Similar to total perception score, I used the *t* test and ANOVA to test whether the mean total barrier score was different across different groups of IVs. Results of this descriptive analysis showed that the mean total barrier score was statistically significantly different by age group, gender, educational level, and residence ownership. The mean total barrier score also was significantly different by distance from an animal waste site or farmland (*p* value < .05). The mean total barrier score increased with increase in age group, with the lowest mean total barrier score (14.22) among respondents between the ages of 18 and 34 years and the highest mean total barrier score (17.14) respondents 75 to 85 years of age. Male respondents had a significantly higher mean total barrier score (16.67) than female respondents (15.23).

Similar to the stepwise pattern seen with each age group, the mean total barrier score increased with education level, suggesting that respondents with higher levels of education perceived that there were stronger barriers to community collaboration more so than respondents with lower levels of education did. The mean total barrier score was 16.83 for respondents with a graduate degree and 13 for respondents with no high school diploma. Respondents who owned their residences (16.39) had higher levels of barriers to community collaboration than respondents who did not own their residences (14.88). Respondents who lived between 5 and 15 miles from an animal waste site or farmland had a higher mean total barrier score (17.16) than respondents who lived more than 5 or 15 miles from an animal waste site or farmland.

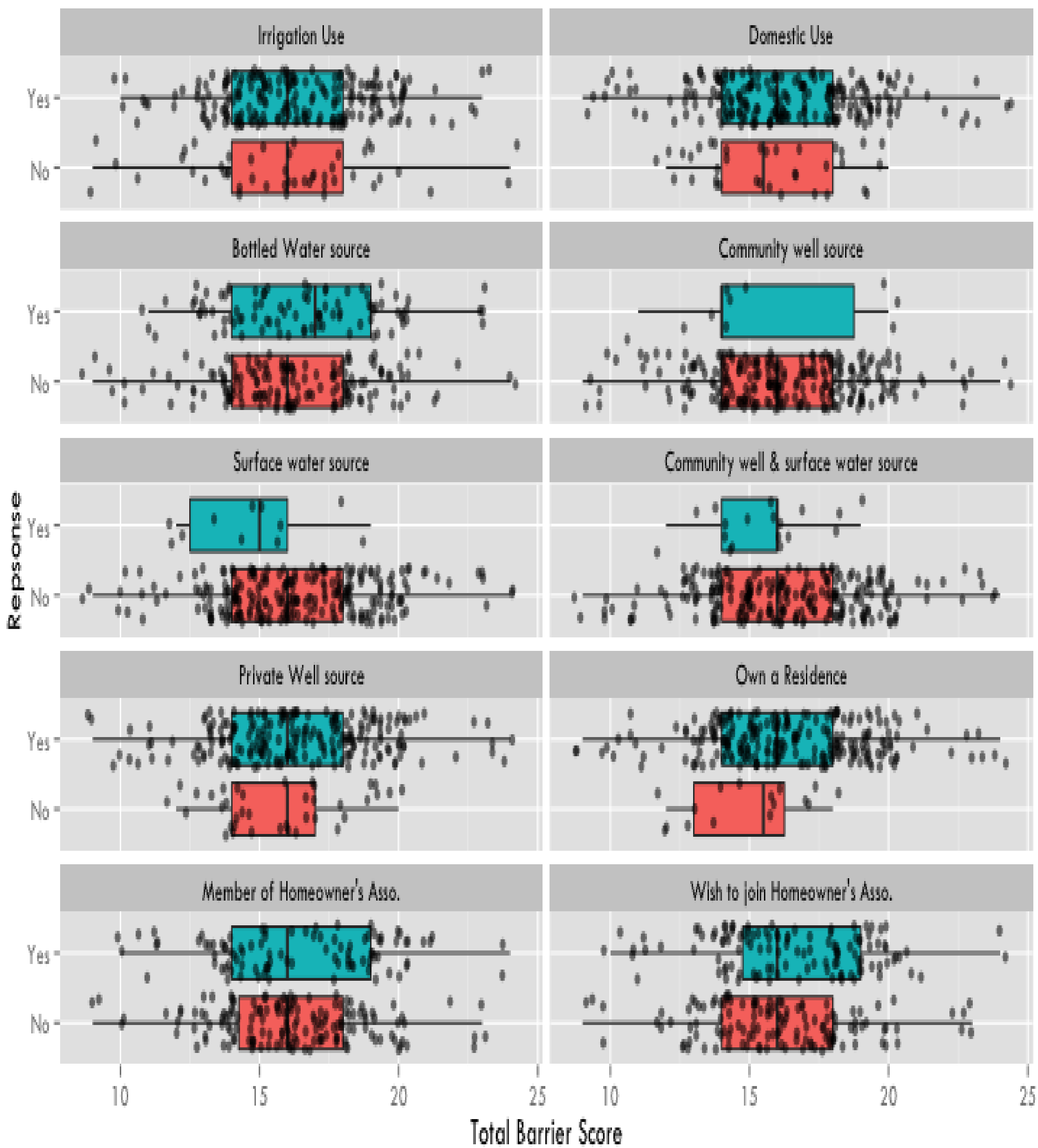
Table 4

*Distribution of Total Barrier Score*

| IVs | | Category | Barrier | Statistic | *p* value |
|---|---|---|---|---|---|
| Use of private Well | Irrigation use | No | 15.89 (9 - 24) | -0.904 | .37 |
| | | Yes | 16.36 (10 - 23) | | |
| | Domestic use of water | No | 15.67 (12 - 20) | -1.588 | .118 |
| | | Yes | 16.37 (9 - 24) | | |
| | Other use | No | 16.24 (9 - 24) | -0.691 | .505 |
| | | Yes | 16.8 (14 - 20) | | |
| Source of drinking water | Community well | No | 16.31 (9 - 24) | 0.774 | .458 |
| | | Yes | 15.5 (11 - 20) | | |
| | Surface water | No | 16.35 (9 - 24) | 2.169 | .052 |
| | | Yes | 14.73 (12 - 19) | | |
| | Community well or surface water | No | 16.35 (9 - 24) | 1.895 | .07 |
| | | Yes | 15.44 (12 - 19) | | |
| | Private well | No | 15.74 (12 - 20) | -1.523 | .133 |
| | | Yes | 16.38 (9 - 24) | | |
| | Bottled water | No | 16.16 (9 - 24) | -0.908 | .365 |
| | | Yes | 16.49 (11 - 23) | | |
| Age | | 18-34 yr | 14.22 (11 - 18) | 6.115 | < .001* |
| | | 35-54 yr | 15.51 (10 - 20) | | |
| | | 55-65 yr | 16.78 (11 - 22) | | |
| | | 65-74 yr | 16.89 (9 - 23) | | |
| | | 75-85 yr | 17.14 (13 - 24) | | |
| Gender | | Female | 15.23 (10 - 24) | -3.711 | < .001* |
| | | Male | 16.67 (9 - 23) | | |
| Education | | High school diploma | 14.78 (10 - 18) | 3.79 | .011* |
| | | Some college courses | 15.75 (10 - 20) | | |
| | | Bachelor’s degree | 16.22 (10 - 23) | | |
| | | Graduate degree | 16.83 (9 - 24) | | |
| Own a residence | | No | 14.88 (12 - 18) | -2.798 | .011* |
| | | Yes | 16.39 (9 - 24) | | |
| LOS in county | | All my life | 16.36 (10 - 22) | 0.166 | .919 |
| | | > 10 yr | 16.3 (9 - 24) | | |
| | | 5-9 yr | 15.91 (10 - 21) | | |
| | | < 5 yr | 16.15 (12 - 21) | | |
| Distance from animal waste site or farmland | | <5 miles | 15.81 (9 - 22) | 4.283 | .006* |
| | | > 5 to < 10 miles | 17.16 (11 - 24) | | |
| | | > 10 to < 15 miles | 17.18 (12 - 20) | | |
| | | > 15 miles | 16.15 (12 - 20) | | |
| Member of homeowner association | | No | 16.2 (9 - 23) | -0.511 | .61 |
| | | Yes | 16.39 (10 - 24) | | |
| Consider joining homeowners association | | No | 16.04 (9 - 23) | -1.426 | .155 |
| | | Yes | 16.55 (10 - 24) | | |

*Note.* *p value < .05

Figure 3 shows the distribution of the total barrier score by IV using boxplots to depict how the total barrier scores were distributed based upon the number of responses. Total barrier scores were normally distributed when compared by different categorical independent variable (IVs). The *t* test was appropriate for the comparison of mean total barrier score in different categories. Boxplots were used to describe the continuous variables. As shown in Table 1, total barrier score was a continuous variable. In this figure, the total barrier score was normally distributed by different independent variables (IVs). Overall, the boxplot shows the distribution of scores by categorical variables.



Irrigation Use
Domestic Use
Bottled Water source
Community well source
Surface water source
Community well & surface water source
Private Well source
Own a Residence
Member of Homeowner's Asso.
Wish to join Homeowner's Asso.
Yes
No
Repsonse
10
15
20
25
Total Barrier Score

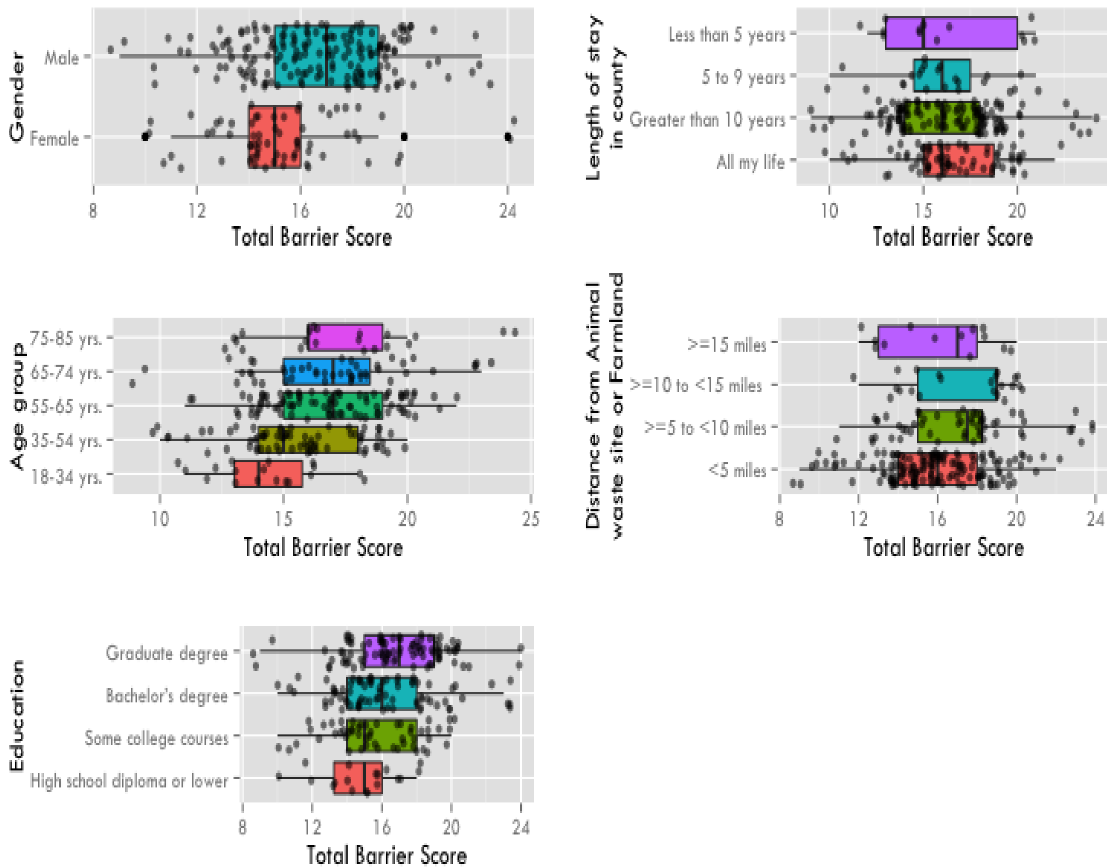



*Figure 3.* Distribution of total barrier score by IV.

**Simple Linear Regression Model and Total Perception Score**

A simple linear regression model was fit for each IV; total perception score as the outcome variable. The result of each simple linear regression model is shown in Table 5. Only the variable of irrigation use showed a statistically significant association with total perception score. The mean total perception score was higher by 1.71 among respondents who used their wells for irrigation than for those who did not ($p$ value < .01).

Table 5

*Simple Linear Regression Model With Total Perception Score as Outcome Variable*

| IVs | | Beta estimate | *t* value | *p* value | 95% CI |
|---|---|---|---|---|---|
| Irrigation use | Intercept | 17.79 | 36.87 | < .001* | 16.84, 18.74 |
| | Yes | 1.71 | 3.19 | < .001* | 0.65, 2.77 |
| Domestic use | Intercept | 19.64 | 34.96 | < .001* | 18.53, 20.75 |
| | Yes | -0.56 | -0.91 | .36 | -1.76, 0.64 |
| Community well source | Intercept | 19.15 | 86.78 | < .001* | 18.72, 19.59 |
| | Yes | -0.35 | -0.33 | .74 | -2.5, 1.79 |
| Surface water source | Intercept | 19.21 | 87.17 | < .001* | 18.77, 19.64 |
| | Yes | -1.48 | -1.43 | .15 | -3.52, 0.56 |
| Community water and surface water | Intercept | 19.07 | 85.12 | < .001* | 18.63, 19.51 |
| | Yes | 0.99 | 1.2 | .23 | -0.63, 2.61 |
| Private well source | Intercept | 19.53 | 35.76 | < .001* | 18.45, 20.6 |
| | Yes | -0.46 | -0.77 | .44 | -1.63, 0.71 |
| Bottled water source | Intercept | 18.85 | 69.86 | < .001* | 18.32, 19.38 |
| | Yes | 0.79 | 1.77 | .08 | -0.09, 1.67 |
| Gender | Intercept | 19.44 | 46.99 | < .001* | 18.62, 20.25 |
| | Male | -0.42 | -0.87 | .39 | -1.38, 0.53 |
| Age | Intercept | 19.94 | 25.31 | < .001* | 18.39, 21.5 |
| | 35-54 yr | -0.48 | -0.54 | .59 | -2.22, 1.26 |
| | 55-65 yr | -0.58 | -0.67 | .51 | -2.28, 1.13 |
| | 65-74 yr | -1.6 | -1.73 | .08 | -3.43, 0.22 |
| | 75-85 yr | -1.66 | -1.54 | .12 | -3.77, 0.46 |
| Education | Intercept | 19.11 | 24.46 | < .001* | 17.57, 20.65 |
| | Some college courses | -1.28 | -1.42 | .16 | -3.07, 0.5 |
| | Bachelor's degree | 0.6 | 0.69 | .49 | -1.11, 2.31 |
| | Graduate degree | 0.28 | 0.33 | .74 | -1.39, 1.96 |
| LOS in county | Intercept | 18.74 | 47.94 | < .001* | 17.97, 19.51 |
| | > 10 yr | 0.58 | 1.19 | .24 | -0.38, 1.54 |
| | 5-9 yr | 0.95 | 1.19 | .24 | -0.63, 2.53 |
| | < 5 yr | -0.05 | -0.05 | .96 | -2.04, 1.94 |
| Distance from animal waste site or farmland | Intercept | 19.03 | 71.05 | < .001* | 18.5, 19.55 |
| | > 5 to < 10 miles | 0.78 | 1.51 | .13 | -0.24, 1.79 |
| | > 10 to < 15 miles | 0.93 | 1.23 | .22 | -0.56, 2.41 |
| | > 15 miles | -2.56 | -2.69 | .01* | -4.44, -0.69 |
| Member of homeowners association | Intercept | 18.97 | 69.2 | < .001* | 18.43, 19.51 |
| | Yes | 0.45 | 1.02 | .31 | -0.42, 1.32 |

Table 5 Cont'd

| IVs | | Beta estimate | *t* value | *p* value | 95% CI |
|---|---|---|---|---|---|
| Consider joining homeowners association | Intercept | 18.86 | 62.74 | < .001* | 18.26, 19.45 |
| | Yes | 0.6 | 1.39 | .17 | -0.25, 1.45 |
| Own a residence | Intercept | 19.56 | 23.39 | < .001* | 17.91, 21.21 |
| | Yes | -0.39 | -0.45 | .65 | -2.1, 1.31 |

*Note*. **p* value < .05

### Multiple Linear Regression and Total Perception Score

Results of the multiple linear regression for RQ1 are presented in Table 6. Total perception score was used as the outcome variable, and age, gender, education, home ownership, length of stay in the area, distance from animal waste site or agricultural property, use of private well, source of drinking water, membership in homeowners or landowners association, and desire to join homeowners or landowners association were used as the IVs. The regression equation for this model was written as the following:

$$
\begin{aligned}
&Total\ Perception\ Score \\
&\quad = \beta_{Age} + \beta_{Gender} + \beta_{Education} + \beta_{Homeownership} + \beta_{Lengthofstay} \\
&\quad + \beta_{DistanceToWasteSite} + \beta_{BottledWater} + \beta_{privateWellDrink} \\
&\quad + \beta_{CommunityWellDrink} + \beta_{SurfaceWaterDrink} \\
&\quad + \beta_{CommunityWellSurfaceWaterDrink} + \beta_{IrrigationUse} + \beta_{DomesticUse}
\end{aligned}
$$

After adjusting for the effects of other covariates (i.e., age, gender, education, homeownership, distance from waste site, source of drinking water, and domestic use of well water) in the model, the mean total perception score of the respondents who used private wells for irrigation was higher by 1.87 than for respondents who did not use private wells for irrigation (*p* value < .05). Similarly, respondents living more than 15 miles away from an animal waste site or farmland had a mean total perception score lower by 2.85 than for respondents living within 5 miles of an animal waste site or farmland ($p$ value < .01). The $p$ value for other IVs did not have a statistically significant association with total perception score. The adjusted $R^2$ showed that only a 10% variability in total perception score was explained by the variables included in the model.

Table 6

*Multiple Regression Model With Total Perception Score as Outcome Variable*

| IVs | | Estimate | *SE* | *t* value | *p* value |
|---|---|---|---|---|---|
| Irrigation use | Yes | 1.88 | 0.60 | 3.10 | .00* |
| | No | | | | Reference |
| Domestic use | Yes | -0.65 | 0.99 | -0.65 | .51 |
| | No | | | | Reference |
| Community well source | Yes | -0.33 | 1.40 | -0.24 | .81 |
| | No | | | | Reference |
| Surface water source | Yes | -0.55 | 1.28 | -0.43 | .67 |
| | No | | | | Reference |
| Community water and surface water | Yes | -0.01 | 1.07 | -0.01 | .99 |
| | No | | | | Reference |
| Private well source | Yes | -0.01 | 1.08 | -0.01 | .99 |
| | No | | | | Reference |
| Bottled water source | Yes | 0.83 | 0.49 | 1.70 | .09 |
| | No | | | | Reference |
| Gender | Male | 0.31 | 0.55 | 0.57 | .57 |
| | Female | | | | Reference |
| Age | 35-54 yr | -0.50 | 1.10 | -0.45 | .65 |
| | 55-65 yr | -0.53 | 1.10 | -0.48 | .63 |
| | 65-74 yr | -1.95 | 1.16 | -1.68 | .10 |
| | 75-85 yr | -1.28 | 1.34 | -0.95 | .34 |
| | 18-34 yr | | | | Reference |
| Education | Some college courses | -1.94 | 1.04 | -1.88 | .06 |
| | Bachelor’s degree | -0.58 | 0.98 | -0.59 | .56 |
| | Graduate degree | -1.05 | 0.98 | -1.07 | .29 |
| | High school diploma or lower | | | | Reference |
| LOS in county | > 10 yr | 0.91 | 0.54 | 1.69 | .09 |
| | 5-9 yr | 1.01 | 0.92 | 1.10 | .27 |
| | < 5 yr | 0.92 | 1.10 | 0.84 | .40 |
| | All my life | | | | Reference |
| Distance from animal waste site or farmland | > 5 to < 10 miles | 0.62 | 0.57 | 1.10 | .27 |
| | > 10 to < 15 miles | 1.07 | 0.84 | 1.27 | .21 |
| | > 15 miles | -2.85 | 1.22 | -2.35 | .02* |
| | < 5 miles | | | | Reference |

Table 6 Cont’d

| IVs | | Estimate | *SE* | *t* value | *p* value |
|---|---|---|---|---|---|
| Member of homeowners association | Yes | -0.24 | 0.62 | -0.39 | .70 |
| | No | | | | Reference |
| Consider joining homeowners association | Yes | 0.60 | 0.57 | 1.05 | 0.30 |
| | No | | | | Reference |
| Own a residence | Yes | -1.17 | 1.13 | -1.04 | 0.30 |
| | No | | | | Reference |
| Intercept | | 19.68 | 1.79 | 11.01 | 0.00* |

*Note.* *$p$ value < .05, observations used: 231, residual *SE*: 3.188, $R^2$: 0.1985, Adj $R^2$: 0.1052

After looking at the results of the multiple linear regression models for RQ1, I rejected Null Hypothesis 1 and concluded that distance from an animal waste site or agricultural property and the use of private wells for irrigation purposes had a statistically significant effect on community perceptions.

Similar to the analysis performed for RQ1, I fitted a simple linear regression model for each IV and total barrier score. In addition, I analyzed the data based upon the categories and groupings of the respondents. A result of these regression models is shown in Table 7. The mean total barrier score was higher by 1.45 among male respondents than among female respondents. A stepwise increase in mean total barrier score also was seen with each older age group. The mean total barrier score was higher by 2.56 among respondents in the age group of 55 to 65 years than for respondents in the age group of 18 to 34 years ($p$ value < .01). Similarly, respondents in the age groups of 65 to 74 years and 75 to 85 years had a mean total barrier score higher by 2.67 and 2.90, respectively, than for respondents between the ages of 18 and 34 years ($p$ value < .01). Respondents with a bachelor’s degree or a graduate degree had a statistically significantly higher mean total barrier score than respondents with a high school diploma or lower education did. In addition, respondents living 5 to 10 miles or 10 to 15 miles from an animal waste site or farmland had a higher mean total barrier score than respondents living within 5 miles of an animal waste site or farmland (*p* value < .05)

Table 7

*Simple Linear Regression Model With Total Barrier Score as Outcome Variable*

| IVs | | Beta estimate | *t* value | *p* value | 95% CI |
|---|---|---|---|---|---|
| Irrigation use | Intercept | 15.89 | 39.18 | < .01* | 15.09, 16.69 |
| | Yes | 0.46 | 1.02 | .31 | -0.43, 1.35 |
| Domestic use | Intercept | 15.67 | 33.86 | < .01* | 14.76, 16.58 |
| | Yes | 0.7 | 1.4 | .16 | -0.28, 1.69 |
| Community well source | Intercept | 16.31 | 89.52 | < .01* | 15.95, 16.67 |
| | Yes | -0.81 | -0.91 | .37 | -2.58, 0.96 |
| Surface water source | Intercept | 16.35 | 90.07 | < .01* | 16, 16.71 |
| | Yes | -1.63 | -1.91 | .06 | -3.31, 0.05 |
| Community water and surface water | Intercept | 16.35 | 88.32 | < .01* | 15.98, 16.71 |
| | Yes | -0.9 | -1.33 | .19 | -2.24, 0.44 |
| Private well source | Intercept | 15.74 | 34.94 | < .01* | 14.85, 16.62 |
| | Yes | 0.64 | 1.31 | .19 | -0.32, 1.61 |
| Bottled water source | Intercept | 16.16 | 72.08 | <.01* | 15.71, 16.6 |
| | Yes | 0.34 | 0.91 | .36 | -0.39, 1.07 |
| Gender | Intercept | 15.23 | 45.51 | < .01* | 14.57, 15.89 |
| | Male | 1.45 | 3.69 | < .01* | 0.67, 2.22 |
| Age | Intercept | 14.22 | 22.63 | < .01* | 12.98, 15.46 |
| | 35-54 yr | 1.28 | 1.83 | .07 | -0.1, 2.67 |
| | 55-65 yr | 2.56 | 3.71 | < .01* | 1.2, 3.92 |
| | 65-74 yr | 2.67 | 3.61 | < .01* | 1.22, 4.13 |
| | 75-85 yr | 2.92 | 3.41 | < .01* | 1.23,4.61 |
| Education | Intercept | 14.78 | 22.97 | < .01* | 13.51, 16.05 |
| | Some college courses | 0.97 | 1.3 | .19 | -0.5, 2.44 |
| | Bachelor’s degree | 1.45 | 2.02 | .04* | 0.04, 2.86 |
| | Graduate degree | 2.06 | 2.93 | < .01* | 0.67, 3.44 |
| LOS in county | Intercept | 16.36 | 50.45 | < .01* | 15.73, 17 |
| | > 10 yr | -0.07 | -0.16 | .87 | -0.86, 0.73 |
| | 5-9 yr | -0.45 | -0.68 | .5 | -1.76,0.86 |
| | < 5 yr | -0.21 | -0.25 | .8 | -1.86,1.44 |
| Distance from animal waste site or farmland | Intercept | 15.81 | 71.62 | < .01* | 15.37,16.24 |
| | > 5 to < 10 miles | 1.35 | 3.18 | < .01* | 0.51,2.19 |
| | > 10 to < 15 miles | 1.37 | 2.21 | .03* | 0.15,2.6 |
| | > 15 miles | 0.34 | 0.44 | .66 | -1.2,1.89 |
| Member of homeowners association | Intercept | 16.2 | 71.37 | < .01* | 15.75,16.65 |
| | Yes | 0.19 | 0.53 | .6 | -0.53, 0.91 |
| Consider joining homeowners association | Intercept | 16.04 | 64.47 | < .01* | 15.55, 16.53 |
| | Yes | 0.51 | 1.43 | .15 | -0.19, 1.22 |
| | | | | | Table 7 Cont’d |
| Own a residence | Intercept | 14.87 | 21.49 | < .01* | 13.51, 16.24 |

| IVs | Beta estimate | *t* value | *p* value | 95% CI |
|---|---|---|---|---|
| Yes | 1.51 | 2.11 | .04* | 0.1, 2.93 |

*Note*. **p* value < .05

**Multiple Linear Regression Model and Total Barrier Score**

I fitted a multiple linear regression model to evaluate the hypothesis for RQ2. I used the total barrier score as the outcome variable and age, gender, education, home-ownership, length of stay in the area, distance from animal waste sites or agricultural property, use of private well, source of drinking water, membership in homeowners or landowners association, and desire to join homeowners or landowners association as the IVs. Regression equation for this model was written as the following:

$$
\begin{aligned}
&Total\ Barrier\ Score \\
&\quad = \beta_{Age} + \beta_{Gender} + \beta_{Education} + \beta_{Homeownership} + \beta_{Lengthofstay} \\
&\quad + \beta_{DistanceToWasteSite} + \beta_{BottledWater} + \beta_{privateWellDrink} \\
&\quad + \beta_{CommunityWellDrink} + \beta_{SurfaceWaterDrink} \\
&\quad + \beta_{CommunityWellSurfaceWaterDrink} + \beta_{IrrigationUse} + \beta_{DomesticUse}
\end{aligned}
$$

The mean total barrier score among male respondents was higher by 1.22 than for female respondents. This effect of gender was adjusted for effects of other covariates in the model and was still statistically significant (*p* value = .01). Likewise, after adjusting for the effects of other IVs, the respondents who lived between 5 and 10 miles away from an animal waste site or farmland had a mean total barrier score higher by 1.43 than for respondents who lived within 5 miles of an animal waste site or farmland (*p* value = 0). Respondents ages 75 years or higher had a greater mean total barrier score (higher by

2.15) than respondents between the ages of 18 and 34 years did. The association between age and total barrier score was statistically significant ($p$ value < .05; see Table 8).

Table 8

*Multiple Regression Model With Total Barrier Score as Outcome Variable*

| IV | | Estimate | SE | *t* value | *p* value |
|---|---|---|---|---|---|
| Irrigation use | Yes | 0.55 | 0.50 | 1.10 | .27 |
| | No | | | | Reference |
| Domestic use | Yes | -0.72 | 0.82 | -0.88 | .38 |
| | No | | | | Reference |
| Community well source | Yes | -1.02 | 1.15 | -0.89 | .38 |
| | No | | | | Reference |
| Surface water source | Yes | -1.66 | 1.05 | -1.59 | .11 |
| | No | | | | Reference |
| Community water and surface water | Yes | -1.41 | 0.88 | -1.60 | .11 |
| | No | | | | Reference |
| Private well source | Yes | -0.12 | 0.89 | -0.14 | .89 |
| | No | | | | Reference |
| Bottled water source | Yes | 0.14 | 0.40 | 0.36 | .72 |
| | No | | | | Reference |
| Gender | Male | 1.22 | 0.45 | 2.71 | .01* |
| | Female | | | | Reference |
| Age | 35-54 yr | 0.88 | 0.91 | 0.97 | .33 |
| | 55-65 yr | 1.65 | 0.90 | 1.83 | .07 |
| | 65-74 yr | 1.72 | 0.95 | 1.80 | .07 |
| | 75-85 yr | 2.15 | 1.10 | 1.95 | .05 |
| | 18-34 yr | | | | Reference |
| Education | Some college courses | 0.32 | 0.85 | 0.37 | 0.71 |
| | Bachelor’s degree | 0.54 | 0.80 | 0.68 | 0.50 |
| | Graduate degree | 0.94 | 0.81 | 1.17 | .24 |
| | High school diploma or lower | | | | Reference |
| LOS in county | > 10 yr | -0.36 | 0.44 | -0.80 | .42 |
| | 5-9 yr | -0.43 | 0.76 | -0.57 | .57 |
| | < 5 yr | 1.18 | 0.90 | 1.31 | .19 |
| | All my life | | | | Reference |
| Distance from animal waste site or farmland | > 5 to < 10 miles | 1.43 | 0.47 | 3.05 | < .001* |
| | > 10 to < 15 miles | 1.17 | 0.69 | 1.69 | .09 |
| | > 15 miles | 0.92 | 1.00 | 0.92 | .36 |

Table 8 Cont’d

| IV | | Estimate | SE | *t* value | *p* value |
|---|---|---|---|---|---|
| | < 5 miles | | | | Reference |
| Member of homeowner association | Yes | -0.11 | 0.51 | -0.21 | .83 |
| | No | | | | Reference |
| Consider joining homeowner's association | Yes | 0.43 | 0.47 | 0.92 | .36 |
| | No | | | | Reference |
| Own a residence | Yes | 0.61 | 0.93 | 0.66 | .51 |
| | No | | | | Reference |
| Intercept | | 12.78 | 1.47 | 8.70 | < .001* |

*Note*. $p$ value < .05, observations used: 231, residual *SE*: 2.621, $R^2$: 0.224, Adj. $R^2$: 0.1336

According to the results in Table 8, I rejected Null Hypothesis 2 and concluded that gender and distance from an animal waste site or farmland had a statistically significant effect on total barrier score.

## Results of the Pilot Study

As mentioned, I pilot tested the final version of the survey with 20 participants to ensure that the questions were clear and reflected the RQs, and to determine the internal consistency of the questionnaire. I would have added or removed questions to improve the validity and reliability of the survey based upon the performance, suggestions, and recommendations of the pilot study participants, but no such change was needed. I used Cronbach's alpha to determine that the coefficient for the internal consistency and reliability of the two composite scores was .70 or more for the pilot study.

## Data Collection

A total of 1,310 surveys were selected from a list of randomly selected 4,000 residents with private wells. The original list came from the OWRB's public website. I used Microsoft Excel's RAND function to generate random numbers. I then assigned one random number to each address where a private well was located using a function called

INDEX.

The initial mailing list had 600 surveys. I received 100 surveys, but 110 surveys were returned undelivered for several reasons: (a) not deliverable as addressed, (b) no such street address, (c) vacant buildings, (d) no mail receptacle, (e) no such number, (f) no such street, and (g) homeowners on vacation. A follow-up reminder letter was sent 2 weeks later to those on the first mailing list who has not yet completed and returned the survey (see Appendix E). For the second mailing list, I sent out another 710 surveys (I reused the 110 undelivered surveys plus another 600) to randomly selected participants.

## Conclusion and Summary

Chapter 4 began with details about the data collection and descriptive analysis processes. I used the *t* test and ANOVA to compare the mean total perception score and total barrier score of each IV. I tested the two hypotheses using simple linear regression and multiple linear regression, respectively. After adjusting for the effects of other covariates in the model, I found that the respondents who used private wells for irrigation had higher levels of perception about community collaboration to achieve groundwater sustainability than respondents who did not ($p$ value $< .05$). Similarly, respondents living more than 15 miles away from an animal waste site or farmland had lower mean levels of perception about community collaboration to achieve groundwater sustainability than respondents living within 5 miles of an animal waste site or farmland did ($p$ value $< .01$). I rejected Null Hypothesis 1 and concluded that use of private wells for irrigation and distance from an animal waste site or farmland was associated with community members' perceptions of community collaboration to achieve groundwater sustainability.

The regression analysis for RQ2 showed that after adjusting for the effects of other covariates in the model, the male respondents had higher levels of perception of the barriers to community collaboration to achieve groundwater sustainability than the female respondents did (*p* value = .01). Likewise, after adjusting for the effects of other IVs, the respondents who lived between 5 and 10 miles of an animal waste site or farmland also had higher levels of perceptions of the barriers to community collaboration to achieve groundwater sustainability than respondents who lived within 5 miles of an animal waste site or farmland did (*p* value < .01). In addition, respondents ages 75 years or higher had greater levels of perception of the barriers to community collaboration to achieve groundwater sustainability (mean total barrier score higher by 2.15) than respondents ages 18 to 34 years (*p* value < .05). I rejected Null Hypothesis 2 and concluded that gender, age group, and distance from an animal waste site or farmland were associated with perceptions to barriers to community collaboration to achieve groundwater sustainability.

In Chapter 5, I discuss the results observed in this study and compare them to the previous published literature. I also discuss the limitations of this study, explain the implications, and offer recommendations for future research.

# Chapter 5: Discussion, Conclusions, and Recommendations

## Introduction

The purpose of this quantitative study was to examine data describing nitrate concentration and cases of congenital cardiac defects. I explored community members' perceptions of community collaboration as a way of sustaining private water wells. I also sought to determine whether certain demographic variables (e.g., gender, home ownership and residence duration, education, and drinking water usage) influenced individual perceptions of the ways in which communities could collaborate to mitigate health threats in private well water sources or whether the variables revealed barriers to such community collaboration that needed to be removed. I did not use the study to determine causal relationships or associations because of data limitations or confounders. As such, the study can serve only as a platform to generate hypotheses for future research.

## Interpretation of the Findings

I tested RQ1 and RQ2 with simple linear regression and multiple linear regression. After adjusting for the effects of other covariates in the model, it became evident that the respondents who used private wells for irrigation had higher levels of perception about community collaboration to achieve groundwater sustainability compared to respondents who did not use private well for irrigation ($p$ value < .05). Similarly, respondents living more than 15 miles *away from* an animal waste site or farmland had lower mean levels of perception about community collaboration to achieve groundwater sustainability than respondents living *within* 5 miles of an animal waste site or farmland ($p$ value < .01). Hence, I rejected null hypothesis 1 and concluded that the use of private wells for irrigation and distance from an animal waste site or farmland were associated with community members' perceptions of community collaboration to achieve groundwater sustainability.

Regression analysis for RQ2 showed that, after adjusting for the effects of other covariates in the model, the male respondents perceived higher level of barriers to community collaboration to achieve groundwater sustainability than the female respondents did ($p$ value = .01). Likewise, after adjusting for the effects of other IVs, the respondents who lived between 5 and 10 miles from an animal waste site or farmland also had higher levels of perception of the barriers to community collaboration to achieve groundwater sustainability than did the respondents who lived within 5 miles of an animal waste site or farmland ($p$ value < .01). In addition, the respondents age 75 years or older had higher levels of perception of the barriers to community collaboration to achieve groundwater sustainability (mean Total Barrier Score higher by 2.15) than respondents between the ages of 18 and 34 years did ($p$ value < .05). I rejected Null Hypothesis 2 and concluded that gender, age group, and distance from an animal waste site or farmland were associated with the perceptions of the barriers to community collaboration to achieve groundwater sustainability.

As mentioned in Chapter 2, few researchers have conducted empirical studies evaluating community members' perceptions of collaboration in and barriers to the management of health threats in private well water sources. There is a need for research to generate information on community members' perceptions of collaboration to achieve groundwater (i.e., private well water) sustainability as well as the barriers to such collaboration among private well users in Oklahoma. Having a better understanding of the opinions, knowledge, and perceptions of the stakeholders will help to ensure a sustainable water system. The data generated from this study will be useful to future researchers by providing an approach to outreach services that might have greater public health benefits for private well users.

The importance of maintaining groundwater quality cannot be overemphasized. Groundwater rules and the goals of the SDWA (1974, as cited in USEPA, 2006), which stipulated that U.S. groundwater must be safe from contaminants and meet minimum standards for drinking water. The findings of this study show how the participants perceived environmental resources and natural hazards, as indicated by barriers to community collaboration, such as proximity to an animal waste site or farmland, especially those who lived further away from an animal waste site or farmland. On the other hand, the participants who used private wells for irrigation and were much closer to an animal waste site or farmland were more open to community collaboration than those who did not use private wells for irrigation or lived further away from environmental hazards. As such, the development of public policy that increases awareness of groundwater contaminants with respect to rural communities could help to inform the users of private wells in Oklahoma.

$H_{01}$: Community perceptions are not affected by any demographic factors of the sample. Therefore, I rejected the null hypothesis.

$H_{a1}$: Community perceptions are affected by at least one of the demographic factors of the sample. Therefore, I accepted the alternative hypothesis.

$H_{02}$: Community barriers to stakeholders' collaboration are not affected by any demographic factors of the sample. Therefore, I rejected null hypothesis.

$H_{a2}$: Community barriers to stakeholders' collaboration are affected by at least one of the demographic factors of the sample. Therefore, I accepted the alternative hypothesis.

## Limitations of the Study

The study had several limitations: (a) The problem of nitrate in Oklahoma private water wells might have been unique to the state; (b) a cross-sectional design was appropriate for this study because of its descriptive and exploratory nature (Creswell, 2009), which allowed me to use my limited time and funding to gather, analyze, and interpret data from a sample, even though generalization of the results was limited; and (c) individuals eligible to be in the sample might not have been willing to participate because it was a voluntary, not a mandatory, exercise. The study reflected only the views of the individuals who participated. The results of this study might not be generalizable to other parts of the United States because conditions and other environmental factors might be different. I also described nitrate concentration and cases of congenital cardiac defects across the state. Because of limitations of data, confounders, and the complexity of the study, I described only the nature of existing data on nitrate concentration and cases of congenital cardiac defects.

# Recommendations

## Recommendations for Action

1. Advocate for increased public health awareness of the important health benefits of testing private wells on a routine basis for rural communities.
2. Encourage different levels of government to educate the general public, especially private water well users, on the need to collaborate on the management of wells by providing information about ways to access information on their websites.
3. Support homeowners associations in their efforts to provide links to public website for information on private well maintenance.
4. Encourage cities to consider putting several groundwater monitoring wells and installing transducers or using existing wells and providing groundwater level information on their websites or billboards to raise public awareness and interest in groundwater levels and conservation when water use is high and groundwater levels are declining. This endeavor will provide real-time information on groundwater depletion and the need for conservation.
5. Solicit help from local, state, and federal governments to test private wells for bacteria and other contaminants as a public health service, or lobby government to provide a link where private owners can get information on where to take their water samples for testing.

## Recommendations for Future Research

1. Research private well users focusing on income, education, and water use and water quality outside Oklahoma County.
2. Obtain community members' perceptions of collaboration to achieve groundwater (i.e., private well water) sustainability and the perceived barriers to such collaboration among private well users in larger and more geographically heterogeneous populations in Oklahoma or the broader United States.
3. Explore factors/variables not considered in this study, but could be associated with perceptions of community collaboration and barriers to collaboration in future research.

## Implications for Positive Social Change

The implications for positive social change include increased understanding of stakeholders' perceptions of private well nitrate contamination and reduction of the risk factors for birth defects. This study might lead to positive social change in that it could provide (a) a more in-depth understanding of nitrate exposure in private wells, (b) more information on the evidence-based environmental decision-making process used to mitigate health threats through community collaboration, and (c) an approach to outreach services that might provide greater public health benefits for Oklahoma private well users. By identifying the participants' perceived attitudes and barriers to community collaboration among private well owners, I believe that this study can present opportunities for health agencies to provide adequate public health services and increase awareness to the general public.

## Conclusion

Potential threats to groundwater quality are a public health concern that could affect the health of a community, especially in rural areas, where it is not common practice for private well users to test for contaminants (DeSimone, 2009; Embrey & Runkle, 2006). For instance, the United States has no universal standards for testing private wells (Imgrund et al., 2011), even in real estate transactions (Hoppe et al., 2011; Rogan & Brady, 2009). Although individual states have standards related to private well testing for environmental contaminants, the different jurisdictions have their own standards. The lack of a uniform standard for private well testing is the result of no federal or state regulations on private wells in the United States (Imgrund et al., 2011); however, some states have started to move in this direction. For well owners, inconvenience, lack of awareness, and time are the challenges to private well testing (Hexemer et al., 2008). Despite these barriers, it is important to test all public and private wells for nitrates because a high concentration of nitrate in groundwater has been linked to such health outcomes as methemoglobinemia, birth defects, and cancer (Arbuckle, 1988; Fewtrell, 2004; Manassaram et al., 2006).

I examined community members’ perceptions of collaboration in and barriers to the management of health threats in private well water sources. Results were generated on community members’ perceptions of collaboration to achieve groundwater (i.e., private well water) sustainability and the perceived barriers to such collaboration among private well users in Oklahoma. The data generated from this study will be useful in facilitating the design and implementation of effective public health outreach services for greater public health benefits for private well users. The results indicated that gender, age group, and distance from an animal waste site or farmland were perceived as barriers to community collaboration to achieve groundwater sustainability. Respondents who used private well for irrigation had higher levels of perceptions of community collaboration than respondents who did not use private well for irrigation. In addition, the use of private wells for irrigation and distance from an animal waste site or farmland were associated with community members' perceptions of community collaboration to achieve groundwater sustainability.

Overall, this study showcased the need for policymakers to develop or improve awareness and education programs that could encourage private well users to take the steps necessary to ensure that their private water systems are safe (Charrois, 2010; Hexemer et al., 2008; Knobeloch, Christenson, Anderson, & Gorski, 2013; Swistock, Clemens, Sharpe, & Rummel, 2013), even though they are not regulated. A total of 36.6% (*n* = 89) used bottled water for drinking; 84.4% (*n* = 205) used private or domestic wells for drinking; 43% of households used either private or domestic well and bottle water for drinking; and 15.2% (*n* = 37) used public water supplies (i.e., community wells, surface water, or community wells and surface water). The reason for high consumption of bottle water among the respondents may be beyond the scope of this study. Future research should explore these unknown factors. Public education messages directed at private well owners that highlight the importance of routine testing should also encourage community collaboration among private well users.

Multiple linear regression model for RQ1 showed that a 20% variability in total perception score was explained by age, gender, education, home ownership, length of stay in the area, distance from animal waste site or agricultural property, use of private well, source of drinking water, membership in homeowners or landowners association, and desire to join homeowners or landowners association ($R^2$ for model for RQ1 = 0.1985, or 19.85%). The model for RQ2 suggested that a more than 22% variability in total barrier score was explained by these IVs ($R^2$ for model for RQ2 = 0.224, or 22.4%). This result suggested that some factors/variables not considered in this study were associated with the respondents' perceptions of community collaboration and barriers to groundwater sustainability. These unknown factors should be explored in future research.

References


Albertin, A., Sickman, J., Pinowska, A., & Stevenson, R. R. (2012). Identification of nitrogen sources and transformations within karst springs using isotope tracers of nitrogen. *Biogeochemistry, 108*(1-3), 219-232. doi:10.1007/s10533-011-9592-0

Altmann, A. E, Halliday, J. L., & Giles, G. G. (1998). Associations between congenital malformations and childhood cancer: A register-based case-control study. *British Journal of Cancer, 78,* 1244-1249. http://dx.doi.org/10.1038/bjc.1998.662

American Heart Association. (2012). Children with heart defects need early evaluation for related disorders. Retrieved from http://newsroom.heart.org/

Arbuckle, T. E. (1988). Water nitrates and CNS birth defects: A population-based case-control study. *Archives of Environmental Health, 43*(2), 162-167. http://dx.doi.org/10.1080/00039896.1988.9935846

Archer, D. L. (2002). Evidence that ingested nitrate and nitrite are beneficial to health. *Journal of Food Protection, 65*(5), 872-875.

Avery, A. (1999). Infantile methemoglobinemia: Reexamining the role of drinking water nitrates. *Environmental Health Perspectives, 107*(7), 583-586. http://dx.doi.org/ 10.1289/ehp.99107583

Avery, A., & L'hirondel, J. (2003). Nitrate and methemoglobinemia. *Environmental Health Perspectives, 111*(3), A142-A143. http://dx.doi.org/10.1289/ehp.111-a142c

Babbie, E. (2007). *The practice of social science.* Belmont, CA: Thomson Wadsworth.

Backer, L. C., & Tosta, N. (2011). Unregulated drinking water initiative for environmental surveillance and public health. *Journal of Environmental Health, 73*(7), 31-32.

Balazs, C., Morello-Frosch, R., Hubbard, A., & Ray, I. (2011). Social disparities in nitrate-contaminated drinking water in California's San Joaquin Valley. *Environmental Health Perspectives*, *119*(9), 1272-1278. doi:10.1289/ehp.1002878

Balgopal, M., & Wallace, A. (2009). Decisions and dilemmas: Using writing to learn activities to increase ecological literacy. *Journal of Environmental Education, 40*(13), 13-22. http://dx.doi.org/10.3200/JOEE.40.3.13-26

Becker, C. J. (2006). Comparison of groundwater quality in samples from selected shallow and deep wells in the Central Oklahoma Aquifer, 2003-2005. Retrieved from http://pubs.usgs.gov/sir/2006/5084/pdf/sir2006-5084.pdf

Bogovski, P., & Bogovski, S. (1981). Animal species in which N-nitroso compounds induce cancer. *Environmental Health Perspective, 83,* 5-24.

Boice, J. D. Jr., Tawn, E. J.**,** Winther, J. F., Donaldson, S. S., Green, D. M., Mertens, A. C., … Stovall, M. (2003). Genetic effects of radiotherapy for childhood cancer. *Health Physics, 85*(1), 65-80. http://dx.doi.org/10.1097/00004032-200307000-00013

Brender, J., Olive, J., Felkner, M., Suarez, L., Hendricks, K., & Marckwardt, W. (2004). Intake of nitrates and nitrites and birth defects in offspring [Abstract]. *Epidemiology, 15,* S184. http://dx.doi.org/10.1097/00001648-200407000-00487

Brender, J. D., Olive, J. M., Felkner, M., Suarez, L., Marckwardt, W., & Hendricks, K. A. (2004). Dietary nitrites and nitrates, nitrosatable drugs, and neural tube defects. *Epidemiology, 15,* 330-336. http://dx.doi.org/10.1097/01.ede.0000121381.79831.7b

Brender, J. D., Weyer, P. J., Romitti, P. A., Zheng, Q., Werler, M. M., Kelley, K. E., … Canfield, M. A. (2013). Prenatal nitrate intake from drinking water and selected birth defects in offspring of participants in the National Birth Defects Prevention Study. *Environmental Health Perspectives*. http://dx.doi.org/10.1289/ehp.1206249

Brent, R. L. (2004). Environmental causes of human congenital malformations: The pediatrician’s role in dealing with these complex clinical problems caused by a multiplicity of environmental and genetic factors. *Pediatrics, 113,* 957-968.

Bryan, K. S., & Stanton, A. G. (2008). Multiple linear regressions: Accounting for multiple simultaneous determinants of a continuous dependent variable. *Circulation, 117,* 1732-1737. http://dx.doi.org/10.1161/CIRCULATIONAHA.106.654376

Buczyńska, A., & Tarkowski, S. (2005). Environmental exposure and birth outcomes. *International Journal of Occupational Medicine and Environmental Health, 18*(3), 225-232. Retrieved from Medline with Full Text database.

Bukowski, J., Somers, G., & Bryanton, J. (2001). Agricultural contamination of groundwater as a possible risk factor for growth restriction or prematurity. *Journal of Occupational Environmental Medicine, 43,* 377-383. http://dx.doi.org/10.1097/00043764-200104000-00016

Burd, L., Deal, E., Rios, R., Adickes, E., Wynne, J., & Klug, M. G. (2007). Congenital heart defects and fetal alcohol spectrum disorders. *Congenital Heart Disease, 2*(4), 250-255. doi:10.1111/j.1747-0803.2007.00105.x

Burkart, M. R., & Stoner, J. D. (2007). Nitrate in aquifers beneath agricultural systems. *Water Science & Technology, 56*(1), 59-69.

Byrne, J., Rasmussen, S. A., Steinhorn, S. C., Connelly, R. R., Myers, M. H., Lynch, C. F., … Mulvihill, J. J. (1998). Genetic disease in offspring of long-term survivors of childhood and adolescent cancer. *American Journal of Human Genetics, 62*(1), 45-52. http://dx.doi.org/10.1086/301677

Cedergren, M., Selbing, A., & Källén, B. (2002). Geographic variations in possible risk factors for severe cardiac malformations. *Acta Paediatrica*, *91*(2), 222-228. http://dx.doi.org/10.1111/j.1651-2227.2002.tb01699.x

Centers for Disease Control and Prevention. (2011a). Congenital heart defects, data and statistics-NCBDDD. Retrieved from http://www.cdc.gov/

Centers for Disease Control and Prevention. (2011b). Private ground water wells. Retrieved from http://www.cdc.gov/

Charrois, J. A. (2010). Private drinking water supplies: challenges for public health. *Canadian Medical Association Journal, 182*(10), 1061-1064. doi:10.1503/cmaj.090956

Comly, H. H. (1945). Cyanosis in infant caused by nitrates in well water. *Journal of the American Medical Association, 129*(2), 112-116. http://dx.doi.org/10.1001/jama.1945.02860360014004

Craig, R. K. (2010). Adapting water federalism to climate change impacts: Energy policy, food security, and the allocation of water resources. *Environment & Energy Law & Policy Journal, 5,* 183. Retrieved from http://ssrn.com/

Creswell, J. W. (2009). *Research design: Qualitative, quantitative, and mixed methods approaches* (3rd ed.). Thousand Oaks, CA: SAGE.

Criss, R., & Davisson, M. (2004). Guest editorial: Fertilizers, water quality, and human health. *Environmental Health Perspectives*, *112*(10), A536. http://dx.doi.org/10.1093/aje/153.4.325

Croen, L. A., Todoroff, K., & Shaw, G. M. (2001). Maternal exposure to nitrate from drinking water and diet and risk for neural tube defects. *American Journal of Epidemiology, 153*(4), 325-331. http://dx.doi.org/10.1093/aje/153.4.325

Dan-Hassan, M. A., Olasehinde, P. I., Amadi, A. N., Yisa, J. J., & Jacob, J. O. (2012). Spatial and temporal distribution of nitrate pollution in groundwater of Abuja, Nigeria. *International Journal of Chemistry*, *4*(3), 104-112. doi:10.5539ijc.v4n3p104

Dellapenna, J. W. (2011). The evolution of riparianism in the United States. *Marquette Law Review, 95*(1), 53-90.

DeSimone, L. A. (2009). Quality of water from domestic wells in principal aquifers of the United States, 1991-2004: U.S. Geological Survey scientific investigations report 2008-5227. Retrieved from http://pubs.usgs.gov/

Dillman, D. A., Brown, T. L., Carlson, J. E., Carpenter, E. H., Lorenz, F. O., Mason, R., … Songster, R. L. (1995). Effects of category order on answers in mail and telephone surveys. *Rural Sociology, 60*(4), 674-687. http://dx.doi.org/10.1111/ j.1549-0831.1995.tb0060

Dorsch, M. M., Scragg, R. K. R., McMichael, 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,* 473-486.

Embrey, S. S., & Runkle, D. L. (2006). Microbial quality of the nation's groundwater resources, 1993-2004: U.S. Geological Survey scientific investigations report 2006-5290. Retrieved from http://pubs.usgs.gov/

Erdfelder, E., Faul, F., & Buchner, A. (1996). Gpower: A general power analysis program. *Behavior Research Methods, Instruments, & Computers, 28,* 1-11. http://dx.doi.org/10.3758/BF03203630

Fabian, R. S., & Myers, S. (1990). *Statistical summary of groundwater quality data: 1986-1988 and proposed groundwater classification for the major groundwater basins in Oklahoma* (Groundwater and Planning Divisions Oklahoma Water Resources Board Technical Report 90-1). Retrieved from www.owrb.ok.gov/ studies/reports/reportspdf/tr901gwquality.pdf/

Fewtrell, L. (2004). Drinking-water nitrate, methemoglobinemia, and global burden of disease: A discussion. *Environmental Health Perspectives, 112*(14), 1371-1374. doi:10.1289/ehp.7216.http://dx.doi.org/10.1289/ehp.7216

Freedman, D., Cantor, K., Ward, M., & Helzlsouer, K. (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. Retrieved from Academic Search Complete database. http://dx.doi.org/10.1080/00039890009604024

Galaviz-Villa, I., Landeros-Sánchez, C., Castañeda-Chávez, M., Martínez-Dávila, J. P., Pérez-Vázquez, A., Nikolskii-Gavrilov, I., & Lango-Reynoso, F. (2010). Agricultural contamination of subterranean water with nitrates and nitrites: An environmental and public health problem. *Journal of Agricultural Science, 2*(2), 17-30. http://dx.doi.org/10.5539/jas.v2n2p17

Gatseva, P. D., & Argirova, M. D. (2008). High-nitrate levels in drinking water may be a risk factor for thyroid dysfunction in children and pregnant women living in rural Bulgarian areas. *International Journal of Hygiene and Environmental Health, 211*(5), 555-559. http://dx.doi.org/10.1016/j.ijheh.2007.10.002

Gazmararian, J., Curran, J., Parker, R., Bernhardt, J., & DeBuono, B. (2005). Public health literacy in America, an ethical imperative. *American Journal of Preventive Medicine, 28*(3), 317-322. http://dx.doi.org/10.1016/j.amepre.2004.11.004

George, M., Wiklund, L., Aastrup, M., Pousette, J., Thunholm, B., Saldeen, T., … Holmberg, L. (2001). Incidence and geographical distribution of sudden infant death syndrome in relation to content of nitrate in drinking water and groundwater levels. *European Journal of Clinical Investigation, 31*(12), 1083-1094.

Glantz, S. A., & Slinker, B. K. (2000). *Primer of applied regression and analysis of variance* (2nd ed.). New York, NY: McGraw-Hill.

Glanz, K., Rimer, B. K., & Lewis, F. M. (2002). *Health behavior and health education: Theory, research and practice* (3rd ed.). San Francisco, CA: Jossey-Bass.

Green, L. W., Richard, L., & Potvin, L. (1996). Ecological foundations of health promotion. *American Journal of Health Promotion, 10*(4), 270-281. http://dx.doi.org/10.4278/0890-1171-10.4.270

Griesenbeck, J. S., Brender, J. D., Sharkey, J. R., Steck, M. D., Huber, J. C., Jr., Rene, A. A., … Suarez, L. (2010). Maternal characteristics associated with the dietary intake of nitrates, nitrites, and nitrosamines in women of child-bearing age: A cross-sectional study. *Environmental Health, 9*(10). doi:10.1186/1476-069X-9-10

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 Resources, 88,* 182-187. http://dx.doi.org/10.1006/enrs.2002.4331

Gupta, S., Gupta, R., Chhabra, S., Eskiocak, S., Gupta, A., & Gupta, R. (2008). Health issues related to N pollution in water and air. *Current Science, 94*(11), 1469-1477. Retrieved from Academic Search Complete database.

Hexemer, A. M., Pintar, K., Bird, T. M., Zentner, S. E., 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 & Health, 6*(4), 521-525. doi:10.2166/wh.2008.070

Hoppe, B. O., Harding, A. K., Staab, J., & Counter, M. (2011). Private well testing in Oregon from real estate transactions: An innovative approach toward a state-based surveillance system. *Public Health Reports, 126*(1), 107-115.

Huber, J. C., Jr., Brender, J. D., Qi, Z., Sharkey, J. R., Vuong, A. M., Shinde, M. U., … Weyer, P. J. (2013). Maternal dietary intake of nitrates, nitrites and nitrosamines and selected birth defects in offspring: A case-control study. *Nutrition Journal, 12*(1), 1-10. doi:10.1186/1475-2891-12-34

Imgrund, K., Kreutzwiser, R., & de Loë, R. (2011). Influences on the water testing behaviors of private well owners. *Journal of Water & Health, 9*(2), 241-252. doi:10.2166/wh.2011.139

Johnson, K. S. (2008). Principal ground-water resources of Oklahoma: Earth sciences and mineral resources of Oklahoma [Educational Publication 9]. Retrieved from http://www.ogs.ou.edu/

Jones, A. Q., Dewey, C. E., Doré, K., Majowicz, S. E., McEwen, S. A., David, W., … Henson, S. J. (2006). Public perceptions of drinking water: A postal survey of residents with private water supplies. *BMC Public Health, 6,* 94. doi:10.1186/ 1471-2458-6-94

Karimzadeh, L., Koohdani, F., Siassi, F., Mahmoudi, M., Moslemi, D., & Safari, F. (2012). Relation between nitrate and nitrite food habits with lung cancer. *Journal of Experimental Therapeutics & Oncology, 10*(2), 107-112.

Katz, B., Sepulveda, A., & Verdi, R. (2009). Estimating nitrogen loading to ground water and assessing vulnerability to nitrate contamination in a large karstic springs basin, Florida. *Journal of the American Water Resources Association, 45*(3), 607-627. doi:10.1111/j.1752-1688.2009.00309.x

Kim, G., Lee, H., Lim, Y., Jung, M., & Kong, D. (2010). Baseflow contribution to nitrates in an urban stream in Daejeon, Korea. *Water Science & Technology, 61*(12), 3216-3220. doi:10.2166/wst.2010.245

Kim, S., Peel, J. L., Hannigan, M. P., Dutton, S. J., Sheppard, L., Clark, M. L., & Vedal, S. (2012). The temporal lag structure of short-term associations of fine particulate matter chemical constituents and cardiovascular and respiratory hospitalizations. *Environmental Health Perspectives, 120*(8), 1094-1099. doi:10.1289/ehp.110472

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. http://dx.doi.org/10.1111/j.1752-1688.2006.tb04508.x

Kleinbaum, D. G., Kupper, L. L., Muller, K. E., & Nizam, A. (1997). *Applied regression analysis and multivariable methods* (3rd ed.). Boston, MA: Duxbury.

Knobeloch, L., Christenson, M., Anderson, H., & Gorski, P. (2013). Private drinking water quality in rural Wisconsin. *Journal of Environmental Health, 75*(7), 16-20.

Lingytė, K., & Česonienė, L. (2009). Effect of new organic fertilizers on the nutrient leaching into groundwater. *Proceedings of the International Scientific Conference: Rural Development, 4*(1), 38-42.

Lofland, J., & Lofland, H. (1995). *Analyzing social settings: A guide to qualitative observation and analysis* (3rd ed.). Davis, CA: Wadsworth.

Magdo, H., Forman, J., Graber, N., Newman, B., Klein, K., Satlin, L., … Landrigan, P. J. (2007). Grand rounds: Nephrotoxicity in a young child exposed to uranium from contaminated well water. *Environmental Health Perspectives, 115*(8), 1237-1241.

Manassaram, D. M., Backer, L., & Moll, D. (2006). A review of nitrates in drinking water maternal exposure and adverse reproductive and developmental outcomes. *Environmental Health Perspectives, 114*(3), 320-327. doi:10.1289/ehp.8407

Manassaram, D. M., Backer, L. C., Messing, R., Fleming, L. E., Luke, B., & Monteilh, C. P. (2010). Nitrates in drinking water and methemoglobin levels in pregnancy: A longitudinal study. *Environmental Health: A Global Access Science Source, 9,* 60-71. doi:10.1186/1476-069X-9-60

Maria, E., Popescu, A., Cornitescu, G., Puiu, I., & Florescu, C. (2012). Types of cardiac heart defects in infants. *Acta Medica Transilvanica, 17*(4), 262-265.

Mateja, W. A., Nelson, D. B., Kroelinger, C. D., Ruzek, S., & Segal, J. (2012). The association between maternal alcohol use and smoking in early pregnancy and congenital cardiac defects. *Journal of Women's Health, 21*(1), 26-34. doi:10.1089/jwh.2010.2582

Mattix, K. D., Winchester, P. D., & Scherer, L. R. (2007). Incidence of abdominal wall defects is related to surface water atrazine and nitrate levels. *Journal of Pediatric Surgery*, *42*(6), 947-949. http://dx.doi.org/10.1016/j.jpedsurg.2007.01.027

McElroy, J. A., Trentham-Dietz, A., Gangnon, R. E., Hampton, J. M., Bersch, A. J., Kanarek, M. S., & Newcomb, P. A. (2008). Nitrogen-nitrate exposure from drinking water and colorectal cancer risk for rural women in Wisconsin, USA. *Journal of Water & Health*, *6*(3), 399-409. doi:10.2166/wh.2008048

Mendes, M. P., Ribeiro, L. L., Nascimento, J. J., Condesso de Melo, T. T., Stigter, T. Y., & Buxo, A. A. (2012). A groundwater perspective on the river basin management plan for central Portugal - Developing a methodology to assess the potential impact of N fertilizers on groundwater bodies. *Water Science & Technology*, *66*(10), 2162-2169. doi:10.2166/wst.2012.427

Mirvish, S., Weisenburger, D. D., Salmasi, S., & Kaplan, P.A. (1987). Carcinogenity of 1-(2-hydroxyethyl)-1-nitrosourea and 3-nitroso-2-oxazolidinone administered in drinking water to male MRC-Wistar rats: Induction of bone, hemopoietic, intestinal, and liver tumors. *Journal of the National Cancer Institute, 78,* 387-393.

Mitacek, E. J., Brunnemann, K. D., Suttajit, M., Caplan, L. S., Gagna, C. E., Bhothisuwan, K., … Martin, N. (2008). Geographic distribution of liver and stomach cancers in Thailand in relation to estimated dietary intake of nitrate, nitrite, and nitrosodimethylamine. *Nutrition & Cancer*, *60*(2), 196-203. doi:10.1080/01635580701649636

Mittelstet, A. R., Smolen, M. D., Fox, G. A., & Adams, D. C. (2011). Comparison of aquifer sustainability under groundwater administrations in Oklahoma and Texas. *Journal of the American Water Resources Association, 47*(2), 424-431. doi:10.1111/j.1752-1688.2011.00524.x

Moons, P., Budts, W., Costermans, E., Huyghe, E., Pieper, P. G., & Drenthen, W. (2009). Pregnancy-related health behavior of women with congenital heart disease: Room for behavioral change interventions. *Congenital Heart Disease, 4*(5), 348-355. doi:10.1111/j.1747-0803.2009.00322.x

Moore, S. W., Satgé, D. D., Sasco, A. J., Zimmermann, A. A., & Plaschkes, J. J. (2003). The epidemiology of neonatal tumours: Report of an international working group. *Pediatric Surgery International, 19*(7), 509-519. doi:10.1007/s00383-003-1048-8

Mueller, D. K., & Helsel, D. R. (1996). Nutrients in the nation’s water-Too much of a good thing? *U.S. Geological Circular,* 1136.

Mulhearn, D. T. (2007). *Community collaboration and restriction of use for the control of invasive threats in multipurpose reservoir* (Doctoral dissertation). Retrieved from Walden University database.

National Birth Defects Prevention Network. (2010). Birth defects state profile – Oklahoma Selected birth defects counts and birth prevalence, Oklahoma and US. Retrieved from http://www.nbdpn.org/docs/OK_2010_C.pdf

National Institutes of Health. (2011). What are congenital heart defects? Retrieved from http://www.nhlbi.nih.gov/

Oklahoma Department of Environmental Quality. (2006). *The state of Oklahoma water quality assessment integrated report.* Retrieved from http://www.deq.state.ok.us/wqdnew/305b_303d/2006_integrated_report_ entire_document.pdf

Oklahoma Department of Environmental Quality. (2010). Private water wells data between 1999 and 2008. Retrieved from http://www.deq.state.ok.us/

Oklahoma State Department of Health. (2003). *Health care information: A summary of major activities and accomplishments of health care information (HCI).* Retrieved from http://www.ok.gov/health2/documents/annual%20report.pdf/

Oklahoma State Department of Health. (2012). Birth defects in Oklahoma. *Pregnancy Risk Assessment Monitoring System, 16*(2). Retrieved from http://www.ok.gov/health2/documents/PramsGram_BirthDefects_Oct2012.pdf

Oklahoma Water Resources Board. (2011). *Oklahoma comprehensive water plan supplement report: Water quality issues & recommendations.* Retrieved from http://www.owrb.ok.gov/supply/ocwp/pdf_ocwp/WaterPlanUpdate/draftreports/OCWP_WaterQuality_IssuesRecs.pdf/

Oklahoma Water Resources Board. (2013). Groundwater studies. Retrieved from http://www.owrb.ok.gov/

Orr, D. (2004). *Earth in mind: On education, environment, and the human prospect.* Washington, DC: First Island Press.

Osborn, N. I., Eckenstein, E., & Koon, K. Q. (1998). Vulnerability assessment of twelve major aquifers in Oklahoma (Oklahoma Water Resources Board Technical Report 98-5). Oklahoma City: Oklahoma Water Resources Board.

Osborn, N. I., & Hardy, R. H. (1999). Statewide groundwater vulnerability map of Oklahoma (Oklahoma Water Resources Board Technical Report 99). Retrieved from www.owrb.ok.gov/studies/reports/gwvulnerability/entire-report.pdf

Ostro, B., Roth, L., Malig, B., & Marty, M. (2009). The effects of fine particle components on respiratory hospital admissions in children. *Environmental Health Perspectives, 117*(3), 475-480. http://dx.doi.org/10.1289/ehp.11848

Page, R. M., Cole, G. E., & Timmreck, T. C. (1995). *Basic epidemiological methods and biostatistics: A practical guidebook.* Boston, MA: Jones and Bartlett.

Pawełczyk, A. (2012). Assessment of health hazard associated with nitrogen compounds in water. *Water Science Technology*, *66*(3), 666-672. http://dx.doi.org/10.2166/wst.2012.227

Pearson, K. A. (2010). National Birth Defects Prevention Network: Birth defects state profile – Oklahoma. Retrieved from http://www.nbdpn.org/

Pearson, K. A. (2011). Oklahoma State Department of Health: Oklahoma Birth Defects Registry. Retrieved from http://www.nbdpn.org/

Perlman H. (2013). What percent of the area of the United States do you think is (inland) water? Retrieved from http://ga.water.usgs.gov/

Postma, J., Butterfield, P. W., Odom-Maryon, T., Hill, W., & Butterfield, P. G. (2011). Rural children's exposure to well water contaminants: Implications in light of the American Academy of Pediatrics' recent policy statement. *Journal of the American Academy of Nurse Practitioners, 23*(5), 258-265. doi:10.1111/j.1745-7599.2011.00609.x

Powlson, D. S., Addiscott, T. M., Benjamin, N., Cassman, K. G., de Kok, T. M., Van Grinsven, H., … Van Kessel, C. (2008). When does nitrate become a risk for humans? *Journal of Environmental Quality, 37*(2), 291-295.

Reinik, M. M., Tamme, T. T., Roasto, M. M., Juhkam, K. K., Jurtšenko, S. S., Tenńo, T. T., & Kiis, A. A. (2005). Nitrites, nitrates and N -nitrosoamines in Estonian cured meat products: Intake by Estonian children and adolescents. *Food Additives & Contaminants, 22*(11), 1098-1105. doi:10.1080/02652030500241827

Rindfleisch, A., Malter, A., Ganesan, S., & Moorman, C. (2008). Cross-sectional versus longitudinal survey research: Concepts, findings, and guidelines. *Journal of Marketing Research, 45*(3), 261-279. doi:10.1509/jmkr.45.3.261

Robbins, S. M. (2012). *Private well education for adult residents of Oklahoma* (Doctoral dissertation). Retrieved from Walden University Library database.

Rogan, W., & Brady, M. (2009). Drinking water from private wells and risks to children. *Pediatrics, 123*(6), 1599-1605.

Ross, J. A. (2008). Congenital abnormalities could indicate tumor predisposition. *Hematology/Oncology Today*, 27.

Ryder, P. D. (1996). Groundwater atlas of the United States; Oklahoma, Texas. US Geological Survey publication HA 730-E. Retrieved from http://pubs.usgs.gov/ha/730e/report.pdf

Sabogal, R. (2010). Global environmental health: Sustainability. *Journal of Environmental Health, 73*(3), 26-27.

Schilling, K., & Zhang, Y. K. (2004). Baseflow contribution to nitrate-nitrogen export from a large, agricultural watershed, USA. *Journal of Hydrology, 295*(1), 305-316. http://dx.doi.org/10.1016/j.jhydrol.2004.03.010

Shekofteh, H., Afyuni, M., Hajabbasi, M., Iversen, B. V., Nezamabadi-pour, H., Abassi, F., & Sheikholeslam, F. (2013). Nitrate leaching from a potato field using adaptive network-based fuzzy inference system. *Journal of Hydroinformatics, 15*(2), 503-515. doi:10.2166/hydro.2012.075

Shi, L., & Chia, S. E. (2001). A review of studies on maternal occupational exposures and birth defects, and the limitations associated with these studies. *Occupational Medicine, 51*(4), 230-244. http://dx.doi.org/10.1093/occmed/51.4.230

Slinker, B. K. (1998). The statistics of synergism. *Journal of Molecular Cell Cardiology, 30*, 723-731. http://dx.doi.org/10.1006/jmcc.1998.0655

Smedts, H., Rakhshandehroo, M., Verkleij-Hagoort, A., Vries, J., Ottenkamp, J., Steegers, E., & Steegers-Theunissen, R. (2008). Maternal intake of fat, riboflavin and nicotinamide and the risk of having offspring with congenital heart defects. *European Journal of Nutrition, 47*(7), 357-365. http://dx.doi.org/10.1007/s00394-008-0735-6

Smith, M. G., Hold, G. L., Tahara, E., & El-Omar, E. M. (2006). Cellular and molecular aspects of gastric cancer. *World Journal of Gastroenterology, 12*(19), 2979.

Smithee, D. (2005). *Groundwater quality, standards, and implementation.* Retrieved from http://www.owrb.ok.gov/news/news2/pdf_news2/conference/2005_GWC_Presentations/Smithee.pdf

Smithee, D. (2009). *Basic water science seminar water quality and ground water data Oklahoma Water Resources Board.* Retrieved from http://www.owrb.ok.gov/supply/ocwp/pdf_ocwp/WaterPlanUpdate/waterscienceseminar/SmitheeData.pdf

Speiran, G. K. (2010). Effects of groundwater-flow paths on nitrate concentrations across two riparian forest corridors. *Journal of the American Water Resources Association, 46*(2), 246-260. doi:10.1111/j.1752-1688.2010.00427.x

Stokols, D. (1996). Translating social ecological theory into guidelines for community health promotion. *American Journal of Health Promotion, 10*(4), 282-298. doi:10.4278/0890-1171-10.4.282

Sunitha, V. V., Reddy, B., & Reddy, M. (2012). Groundwater contamination from agro-chemicals in irrigated environment: Field trials. *Advances in Applied Science Research, 3*(5), 3382-3386.

Suvedi, M., & Krueger, D. (2000). Michigan citizens' knowledge and perceptions about groundwater. *Journal of Environmental Education, 31*(2), 16. http://dx.doi.org/10.1080/00958960009598634

Swistock, B. R., Clemens, S., Sharpe, W. E., & Rummel, S. (2013). Water quality and management of private drinking water wells in Pennsylvania. *Journal of Environmental Health, 75*(6), 60-66.

Szajdak, L., Życzyńska-Bałoniak, I., Jaskulska, R., & Szczepański, M. (2009). Changes of the concentrations of dissolved chemical compounds migrating into ground water through biogeochemical barriers in an agricultural landscape. *Oceanological & Hydrobiological Studies, 38*(4), 109-116. doi:10.2478/v10009.-009-0048-y

Tanner, C. (2009). To act or not to act: Nonconsequentialism in environmental decision-making. *Ethics & Behavior, 19*(6), 479-495. http://dx.doi.org/10.1080/1050842 0903275192

Thompson, S. K. (2002). *Sampling* (2nd ed.). New York, NY: Wiley-Interscience.

Thorpe, N., & Shirmohammadi, A. (2005). Herbicides and nitrates in groundwater of Maryland and childhood cancers: A geographic information systems approach. *Journal of Environmental Science & Health, Part C -- Environmental Carcinogenesis & Ecotoxicology Reviews, 23*(2), 261-278. doi:10.1080/1059050 0500235001

Tricker, A. R., & Preussmann, R. (1991). Carcinogenic N-nitrosamines in the diet: occurrence, formation, mechanisms and carcinogenic potential. *Mutation Research/Genetic Toxicology, 259*(3), 277-289. http://dx.doi.org/10.1016/0165-1218(91)90123-4

Trochim, W. M., & Donnelly, J. P. (2007). *Research methods knowledge base* (3rd ed.). Mason, OH: Atomic Dog/Cengage Learning.

Tulupov, V. P., Prikhod'ko, E. I., & Fomichenko, E. I. (2001). Toxicological and hygienic assessment of nitrates in food products. *Voprosy Pitanija, 70*(2), 4-32.

U.S. Department of Health and Human Services. (2010). The National Children's Study. Retrieved from http://www.nationalchidrenstudy.gov

U.S. Environmental Protection Agency. (2002). Nitrification distribution system issue paper. Retrieved from http://water.epa.gov/

U.S. Environmental Protection Agency. (2003). *Drinking water from household wells.* Retrieved from http://water.epa.gov/drink/info/well/upload/2003_06_03_private wells_pdfs_household_ wells.pdf

U.S. Environmental Protection Agency. (2006). Private drinking water wells. Retrieved from http://www.epa.gov/

U.S. Environmental Protection Agency. (2007). *Toxicity and exposure assessment for children's health.* Retrieved from http://www.epa.gov/teach/chem_summ/ Nitrates_ summary.pdf

U.S. Environmental Protection Agency. (2011). *Nitrogen and phosphorus pollution series: Nitrate in groundwater.* Retrieved from http://water.epa.gov/learn/training/ wacademy/upload/2011_3_29_flyer.pdf

U.S. Environmental Protection Agency. (2012a). Denitrification beef glossary Ag 101. Retrieved from http://www.epa.gov/

U.S. Environmental Protection Agency. (2012b). Human health: What are some naturally occurring sources of pollution? Retrieved from http://water.epa.gov/

U.S. Environmental Protection Agency. (2012c). Private well owners. Retrieved from http://www.epagov/

U.S. Environmental Protection Agency. (2013). *Nitrate health effects.* Retrieved from http://www.epa.gov/region9/ag/workshop/nitrogen/2013/macler-nitrate-released.pdf

U. S. Geological Survey. (2013). Garber-Wellington (Central Oklahoma) aquifer study. Retrieved from http://ok.water.usgs.gov/

Van Bochove, E. E., Savard, M. M., Thériault, G. G., Cherif, R. R., Ziadi, N. N., & MacLeod, J. J. (2007). Nitrogen fertilizer impact on the Wilmot watershed aquifer in Prince Edward Island, Canada. *Water Science & Technology, 56*(1), 243-251. http://dx.doi.org/10.2166/wst.2007.458

Van Grinsven, H. M., Rabl, A., & de Kok, T. M. (2010). Estimation of incidence and social cost of colon cancer due to nitrate in drinking water in the EU: A tentative cost-benefit assessment. *Environmental Health: A Global Access Science Source, 9*58-69. doi:10.1186/1476-069X-9-58

Van Grinsven, H. M., Ward, M. H., Benjamin, N., & De Kok, T. M. (2006). Does the evidence about health risks associated with nitrate ingestion warrant an increase of the nitrate standard for drinking water? *Environmental Health, 5,* 26. doi:10.1186/1476-069X-5-26

Vitoria, M. I., Brines, S. J., Morales, S. V., & Llopis, G. A. (1991). Nitrates in drinking water in the Valencia community. *Anales de Pediatría Española, 34*(1), 43-50.

Walker, R. (1990). Nitrates, nitrites and N-nitrosocompounds: A review of the occurrence in food and diet and the toxicological implications. *Food Additives & Contaminants, 7*(6), 717-768. http://dx.doi.org/10.1080/02652039009373938

Ward, M., de Kok, T., 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. doi:10.1289/ehp.8043

Weihe, P., & Grandjean, P. (2012). Cohort studies of Faroese children concerning potential adverse health effects after the mothers' exposure to marine contaminants during pregnancy. *Acta Veterinaria Scandinavica, 54*(Suppl 1), S7.

Weinhold, B. (2010). Nitrate may feed thyroid disorders. *Environmental Health Perspectives, 118*(6), A244. http://dx.doi.org/10.1289/ehp.118-a242 http://dx.doi.org/10.1289/ehp.118-a244a

Wilson, H., Kabogo, J., Evans, J., & Burns, M. (2003). Nitrate and man: Toxic, harmless or beneficial? *Journal of Nutrition Education & Behavior, 35*(5), 274.

Winchester, P. D., Huskins, J., & Ying, J. (2009). Agrichemicals in surface water and birth defects in the United States. *Acta Paediatrica, 98*(4), 664-669. doi:10.1111/j.1651-2227.2008.01207.x

Winther, J. F., Boice, J. D., Frederiksen, K. K., Bautz, A. A., Mulvihill, J. J., Stovall, M. M., & Olsen, J. H. (2009). Radiotherapy for childhood cancer and risk for congenital malformations in offspring: A population-based cohort study. *Clinical Genetics, 75*(1), 50-56. doi:10.1111/j.1399-0004.2008.01109.x

World Health Organization. (2007). *Nitrate and nitrite in drinking water* (Background document for development of World Health Organization guidelines for drinking-water quality; WHO/SDE/WSH/07.01/16). Geneva, Switzerland: Author.

Wyrobek, A. J., Mulvihill, J. J., Wassom, J. S., Malling, H. V., Shelby, M. D., Lewis, S. E., … Bishop, J. B. (2007). Assessing human germ-cell mutagenesis in the postgenome era: A celebration of the legacy of William Lawson (Bill) Russell. *Environmental Molecular Mutagenesis, 48,* 71-95. doi:10.1002/em.20284

Yang, G., Guirui, Y., Chunyan, L., & Pei, Z. (2012). Groundwater nitrogen pollution and assessment of its health risks: A case study of a typical village in rural-urban continuum, China. *Plos ONE, 7*(4), 1-8. doi:10.1371/journal.pone.0033982

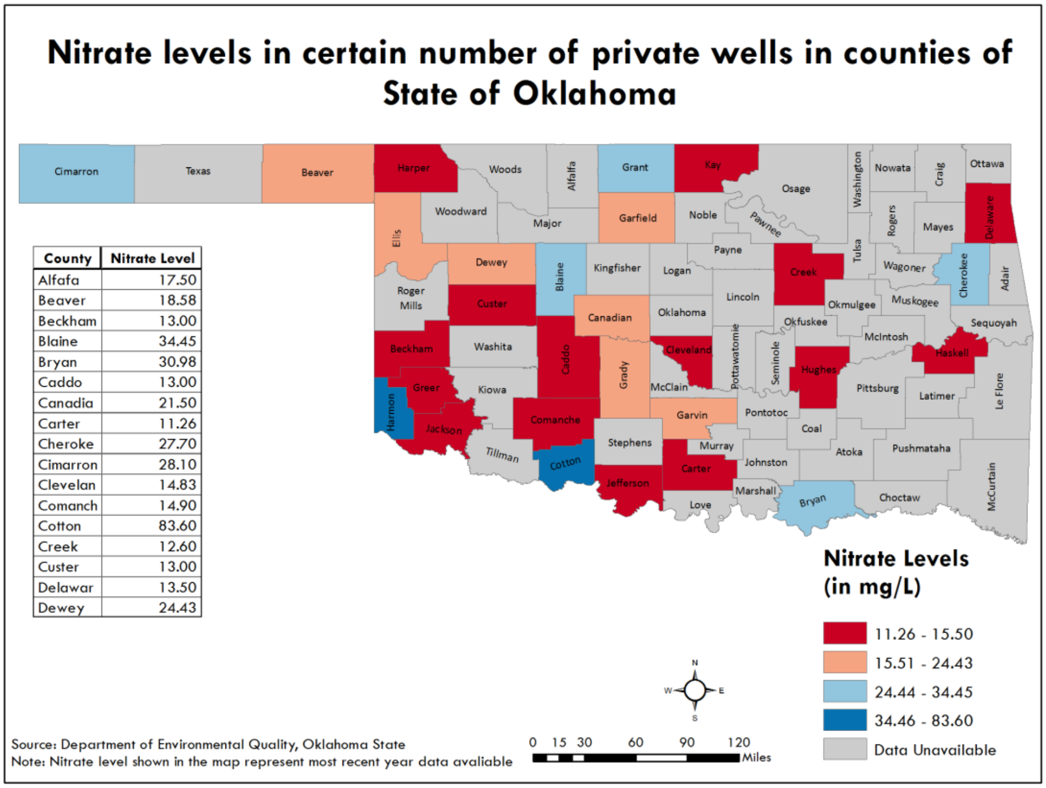
Zeegers, M., Selen, R., Kleinjans, J., Goldbohm, R., & van den Brandt, P. (2006). Nitrate intake does not influence bladder cancer risk: The Netherlands cohort study. *Environmental Health Perspectives, 114*(10), 1527-1531. http://dx.doi.org/ 10.1289/ehp.9098

Zeman, C., Beltz, L., Linda, M., Maddux, J., Depken, D., Orr, J., & Theran, P. (2011). New questions and insights into nitrate/nitrite and human health effects: A retrospective cohort study of private well users' immunological and wellness status. *Journal of Environmental Health, 74*(4), 8-18.

Zierhut, H., Murati, M., Holm, T., Hoggard, E., & Spector, L. (2011). Association of rib anomalies and childhood cancers. *British Journal of Cancer, 105*(9), 1392-1395. doi:10.1038/bjc.2011.366

Zierler, S., Theodore, M., & Cohen, A. (1988). Chemical quality of maternal drinking water and congenital heart disease. *International Journal Epidemiology*, *17*(3), 589-594. doi:10.1093/ije/17.3.589

Appendix A: Available Private Wells Nitrate Data for Counties in Oklahoma 1999-2008




| County | Nitrate Level |
|---|---|
| Alfafa | 17.50 |
| Beaver | 18.58 |
| Beckham | 13.00 |
| Blaine | 34.45 |
| Bryan | 30.98 |
| Caddo | 13.00 |
| Canadia | 21.50 |
| Carter | 11.26 |
| Cheroke | 27.70 |
| Cimarron | 28.10 |
| Clevelan | 14.83 |
| Comanch | 14.90 |
| Cotton | 83.60 |
| Creek | 12.60 |
| Custer | 13.00 |
| Delawar | 13.50 |
| Dewey | 24.43 |

Appendix B: Congenital Heart Defects Data for Oklahoma 1999-2008

| Congenital heart defects/1,000 live births | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | Trend |
| Transposition of great arteries | 0.39 | 0.52 | 0.44 | 0.58 | 0.47 | 0.59 | 0.64 | 0.67 | 0.40 | 0.51 | |
| Tetralogy of fallot | 0.45 | 0.44 | 0.56 | 0.36 | 0.33 | 0.41 | 0.44 | 0.43 | 0.44 | 0.53 | |
| Pulmonary valve atresia-stenosis | 0.52 | 0.66 | 0.90 | 0.54 | 0.77 | 0.78 | 0.56 | 0.70 | 0.49 | 0.53 | |
| Hypoplastic left heart syndrome | 0.23 | 0.22 | 0.22 | 0.14 | 0.37 | 0.29 | 0.29 | 0.31 | 0.15 | 0.13 | |
| Endocardial cushion defect | 0.43 | 0.66 | 0.58 | 0.56 | 0.43 | 0.47 | 0.41 | 0.28 | 0.36 | 0.51 | |
| Carctation of aorta | 0.52 | 0.44 | 0.46 | 0.54 | 0.53 | 0.49 | 0.58 | 0.59 | 0.45 | 0.58 | |
| Aortic valve stenosis | 0.45 | 0.34 | 0.44 | 0.44 | 0.51 | 0.33 | 0.39 | 0.37 | 0.27 | 0.24 | |
| Ventricular septal defect (VSD) | 4.89 | 4.49 | 4.74 | 4.71 | 5.17 | 5.26 | 5.39 | 5.33 | 4.79 | 5.10 | |
| Atrial septal defect (ASD) | 3.96 | 4.89 | 6.50 | 6.28 | 7.47 | 7.70 | 6.68 | 5.41 | 6.53 | 6.63 | |

Source of birth data: Pearson, K. A. (2011). Oklahoma State Department of Health: Oklahoma Birth Defects Registry. Retrieved from http://www.nbdpn.org/

# Appendix C: Sustainability and Community Collaboration Survey

Introductory letter is included in this survey. Please read before completing the survey questionnaire.

## Section A. Definitions and Background Information

For the purposes of this survey, please refer to the following definitions:

*Community perceptions:* These refer to how communities understand and feel about the environment where they live (i.e., Ground water resources).

*Sustainable groundwater or maintainable groundwater*: A water source that meets the health needs of the present without compromising the ability of future generations to meet their water needs; water source to maintain human health and ecosystem health, and be available for future use.

*Restriction of use of groundwater or limitation of use of groundwater*: Laws or regulations that limit or prohibit the use of private well water by the public.

*Community collaboration stakeholders or community cooperation of stakeholders*: A process of water system management in which government managers and the public work together to achieve sustainable or maintainable groundwater.

Please answer the following questions:

Gender: Please circle: M / F

Age: (Please check one):

____18 -34 years

____ 35-54 years

____ 55- 64 years

____ 65-74 years

____ 75-85 years

Do you own your own residence? Yes / No

What is the highest level of education you have achieved (check one only):

____ No high school diploma

____ High school diploma

____ Some college courses

____ Bachelor's degree

____ Graduate degree

How long have you lived in your county? (Please check the one that applies):

____ All my life

____ Greater than 10 years

____ 5 to 9 years

____ Less than 5 years

Approximately how far do you live from an animal waste site or farmland? (Check the one that applies):

____Less than 5 miles

____Greater than 5 miles but less than 10 miles

____Greater than 10 miles but less than 15 miles

____Greater than 15 miles

For which of the following activities do you use private well water (check all that apply):

____ Irrigation (including lawn watering)

____ Domestic use

____Other (please specify):____________

Where do you get your drinking water? (Please check all that apply):

____ Public water supply (community wells only)

____Public water supply (surface water only)

____Public water supply (surface water and community well)

____ A private well

____ Bottled water

____Don’t know

Are you currently a member of a homeowners association? Yes / No

Would you consider joining a homeowners association? Yes / No

Section B. Community Collaboration and Restriction of Use

Please rate your level of agreement with the following statements on a scale from 1 to 5 by circling the appropriate number. Please respond to every question, circling “3” if you are unsure.

1 = strongly disagree
2 = disagree
3 = neither disagree nor agree, or unsure
4 = agree
5 = strongly agree

1. It is not possible to have sustainable groundwater without community collaboration

1 2 3 4 5

2. Restricting private use of groundwater is not as good as increasing community collaboration 1 2 3 4 5

3. It is realistic to think that true community collaboration can be developed 1 2 3 4 5

4. Community collaboration is critical to developing sustainable groundwater 1 2 3 4 5

5. Community collaboration is all that is needed to develop sustainable groundwater

1 2 3 4 5

6. Restricted use (such ban drilling permit or irrigation) is not the best method to develop sustainable groundwater 1 2 3 4 5

Section C. Possible Barriers to Community Collaboration

Please rate your level of agreement with the following statements on a scale from 1 to 5 by circling the appropriate number: Please respond to every question, circling “3” if you are unsure.

1 = strongly disagree
2 = disagree
3 = neither disagree nor agree, or unsure
4 = agree
5 = strongly agree

1. Managers of groundwater systems do not actively encourage community collaboration

1 2 3 4 5

2. Private well owners are not given enough information on private water wells to make informed environmental decisions 1 2 3 4 5

3. The restrictions placed on water use are major and unacceptable as a method to manage the ground water system 1 2 3 4 5

4. The people who live in this area are not the ones who negatively affect the water quality 1 2 3 4 5

5. The individuals in this community do not have much contact with each other about anything 1 2 3 4 5

Are there any other barriers that you believe get in the way of effective community collaboration? If so, please describe them here:

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

# Appendix D: Permission to Modify and Use Survey Instrument

Dear Augustus,

Yes of course you may modify my survey instrument to fit your
research. I would expect that.

Best regards,
David

On 3/25/12, Augustus Jaja <augustus.jaja@waldenu.edu> wrote:
> Dr. Mulhearn,
>
> After reviewing your survey instrument, there is a need for some
> modification of the survey tool to fit my research need. For this reason, i
> am seeking permission from you to modify the instrument to address private
> well users. If you grant me the permission; i will add additional
> questions, and in some cases; questions that does not address private water
> wells users and related research questions will be removed. I will also
> make available the modified version of the instrument to you. I welcome your
> assistance in this matter, and any direction you might offer. Please feel
> free to contact me via augustus.jaja@waldenu.edu or i can also be reached at
> 405-822-4558.
>
> Thanks,
>
> Augustus JaJa, PhD. Candidate
> Walden university College of Health Sciences.
>
>
>
>
>
> Original E-mail
> From :David Mulhearn <mulhearn@maine.edu>
> Date :02/15/2012 05:26 PM
> To :Augustus Jaja <augustus.jaja@waldenu.edu>
> Subject :Re: Survey Instrument (Questionnaire)
>
>
> Dear Augustus,
>
> I am pleased to read that you are interested in pursuing a similar
> research direction. As you aptly state, reaching sustainability of
> water resources must embrace an understanding of the stakeholders
> perceptions. Unfortunately there has been little done to explore the
> issue. As a result I produced the instrument used in my research,
> tested it and used it for the study. You may use it, if you find that
> it fits your study. I would of course ask that you credit it to me. If
> you have obtained a copy of my dissertation you must have seen that

> the instrument is included in the appendix.
>
> When I had completed my research I had thought it would be interesting
> to see further research of this type done in the area of well users. I
> wish you success.
>
> If I can help in any further way don't hesitate to ask,
>
> Regards,
> David
>
>
>
> On 2/15/12, Augustus Jaja wrote:
>>
>>
>> Dr. Mulhearn,
>>
>> My name is Augustus JaJa and I am a PhD Candidate at Walden University. I
>> have a bachelor's degree in both Chemistry and Environmental Health
>> Science
>> and masters of business administration (MBA). My background is in
>> environmental chemistry. Currently, I work as analytical chemist with City
>> of Edmond water resources Department in Oklahoma.
>> I am interested in pursuing my dissertation in the area of private well
>> user's perceptions of groundwater Nitrate concentration, cooperation, and
>> barriers to management of health threats to sources of their drinking
>> water.
>> Understanding stakeholders' perception is critical to achieve
>> sustainability. I have been searching for an instrument that would explore
>> perception of private well users and environmental decision making in
>> rural
>> area.
>> I was delighted when I read your Dissertation titled "Community
>> Collaboration and Restriction of Use for the control of invasive threats
>> in
>> multipurpose Reservoir". I am wondering if the questionnaire is available
>> for use? I appreciate your assistance in this matter and any direction you
>> might offer. Please feel free to contact me at Augustus.jaja@waldenu.edu
>> I
>> can also be reached at 405-822-4558
>>
>> Sincerely,
>>
>> Augustus JaJa, PhD. Candidate
>> Walden University
>> College of Health Sciences
>
>
> --
> Dr David T. Mulhearn
> Ms Debra Koceika
>

> 3165 East University Dr. #307
> Mesa, Arizona 85213
>
> 207 233 2576

--
Dr David T. Mulhearn
Ms Debra Koceika

3165 East University Dr. #307
Mesa, Arizona 85213

207 233 2576

# Appendix E: Follow-Up Letter

Sustainability and Community Collaboration Study of Private Water Wells in Oklahoma

Dear Resident:

Several weeks ago you were asked to participate in a research study conducted by Augustus JaJa, PhD student in the School of Public Health at Walden University. The researcher invited you because Knowledge, Opinions, and Perceptions of Oklahomans over the age of 18 are important. A copy of permission to conduct research was enclosed with survey questionnaire.

This study of sustainability and community collaboration of Private Water Wells in Oklahoma hopes to fill the gaps in the literature and provide scientifically based knowledge regarding perceptions of our groundwater quality thus helping to promote good environmental stewardship.

As a resident in this community, your views about private well sustainability are critically important. A postage paid envelope was enclosed for your convenience. I hope you will complete and return the survey to me so that I may include your response on how we may promote groundwater sustainability.

Thank you for your assistance.

Sincerely,

Augustus JaJa, PhD Candidate

School of Health Sciences

Walden University

Curriculum Vitae

Augustus D. Jaja, PhD Candidate

**EDUCATION**

- AAS, Environmental Technology, Rose State College, OK
- BS, Environmental Health Science, East Central University, OK
- BS, Chemistry, Langston University, Langston, OK
- MBA, University of Phoenix, Phoenix, AZ
- PhD, Candidate in Public Health. Walden University, Minneapolis, MN
- Oklahoma Department of Environmental Quality Certifications:
    - Class “A” Waterworks Laboratory Specialist
    - Class “A” Wastewater Laboratory Specialist
    - Class “A” Wastewater Specialist
    - Class “A” Water Specialist

**PROFESSIONAL**

2008-Present President/CEO, Augstrom Technologies, Inc., OK.

2001-Present Environmental Chemist, Water Resources, Edmond, OK

1999-2001 President/Laboratory Manager, Ace Metal Finishing of OK Inc.

1998-1999 Laboratory/Compliance Manager, Perfection Industries, Inc. OK

**PROFESSIONAL AFFILIATIONS**

- American Chemical Society
- American Water Works Association
- American Public Works Association

- Water Environment Federation
- Oklahoma Water Pollution Control Association
- American Public Health Association