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Drinking Water and Autism: Using Spatial Cluster Detection to Explore Patterns of Autism Cases in Lane County, Oregon

Sherry Sandreth
Walden University

Walden University

College of Health Sciences

This is to certify that the doctoral dissertation by

Sherry Sandreth

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Review Committee
Dr. Frederic Grant, Committee Chairperson, Public Health Faculty
Dr. Linda Lee, Committee Member, Public Health Faculty
Dr. Daniel Okenu, University Reviewer, Public Health Faculty

Chief Academic Officer
Eric Riedel, Ph.D.

Walden University
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Abstract

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Sherry D. Sandreth

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Dissertation Submitted in Partial Fulfillment

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Abstract

Autism Spectrum Disorders (ASD) are a complex array of neurological disorders with a diverse presentation, multiple etiologies, and long-term ramifications. Prevalence of ASD in the United States is about 1 in 50 children as of 2013, making it a significant public health problem. The etiology is not understood, and it is widely accepted that it is multicausal, with genetic and environmental influences. Prior research suggests an association between water source and ASD. Contaminants such as lead, arsenic, mercury, pharmaceuticals and pesticides found in water are associated with developmental disorders suggesting that a systematic review focused on water source was warranted. Following the integrative model of environmental health (IMEH), this study explored the relationship of water source and ASD prevalence among children in Lane County, Oregon. This cross-sectional study utilized retrospective data of 91 open cases in April 2014. The study used chi square and geographical information systems (GIS) aided by cluster analysis to generate risk maps. Investigation of sociodemographic variables allowed comparisons to national data by zip code. Findings indicated no significant relationships or clusters of ASD populations by zip code, and no significant relationships to comorbidities between private or municipal water supplies. The IMEH framework enabled an in-depth data characterization of ASD and underscored the need for additional environmental data and universally standardized comorbidity definitions. Implication for positive social change include recognizing the importance of using social services data in the search for ASD risk factors.

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Dedication

This work is dedicated to my husband, John, my children, Benjamin, Gabriel, Madison, and Bryan, and my rich circle of friends for their unwavering encouragement during the challenges of graduate school. I am truly thankful for my husband's unconditional love and validation, my children's unending respect and inspiration as we attended post-secondary education simultaneously, and my many friends who positively influenced my pursuit and love of science.

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Chapter 1: Introduction to the Study

Overview

This chapter describes the purpose of the study and an overview of the problem of autism and its challenging etiology. The theoretical framework, limitations, and definitions used in the research are presented.

Autism Spectrum Disorder

Autism is a complex array of neurological disorders with a diverse presentation (Kumar et al., 2011), multiple etiologies (Andreica-săndică, Patca, Panaete, & Andreica, 2011) and long-term ramifications. Accordingly, autism spectrum disorders (ASD) encompass impairments in many areas, such as communication, language, social skills, and interests (Kumar et al., 2011). Since 2013, three domains have been related to ASD deficits: social interaction, communication, and presence of repetitive behaviors and interests (Cohen et al., 2013). However, the deficits in social interactions and communication are the hallmarks of ASD (Cohen et al., 2013). Presentation is highly heterogeneous but symptom onset is often before age three (Cohen et al., 2013). Early infancy symptoms can include atypical ability to imitate, detach, and respond to name, body language, and eye contact (Cohen et al., 2013). These symptoms accompany delayed speech and limited interests, typically noticed between 18 and 36 months of age (Cohen et al., 2013). To date, there is neither a known cause nor a cure for ASD.

The Centers for Disease Control and Prevention (CDC) reported that one in 50 U.S. school children are diagnosed with ASD (CDC, 2013). A 5 to 1 ratio of diagnosis exists between boys and girls, and this is consistent between countries (Johnson, Giarelli, Lewis, & Rice, 2012). The 2010 Autism and Developmental Disabilities Monitoring (ADDM) network surveillance found that one in 68 eight-year-old children have ASD (2010). The ADDM also found an increase in the number of children with ASD who have average to above average intellectual ability; however, this varied significantly by location and by race or ethnicity, compared to previous years (CDC, 2015). The rates of autism in eight-year-old children by demographic are shown in Table 1.

Table 1

Prevalence of Autism Spectrum Disorder (ASD) in eight-year-olds

Demographic	**Variable**	**Prevalence**
	Overall	1 in 68
Gender	Boys	1 in 42
	Girls	1 in 189
Race	White	1 in 63
	Black	1 in 81
	Asian/Pacific Islander	1 in 81
	Hispanic	1 in 93

Centers for Disease Control and Prevention (2010).

Heritability and Environmental Influence

Roughly 75% to 80% of ASD cases are idiopathic, meaning no identifiable cause exists, whereas the remaining are inherited (Miles, McCathren, Sticher, & Shinawi, 2010). Stoner et al. (2014) conducted a small study on 11 postmortem ASD brains of children aged 2–15 years, and found disorganized neocortical architecture in all but one brain, indicating that autism develops in-utero during cortex development between 19 and

32 weeks of gestation. Many researchers believe the causes of ASD are multifaceted with genetics only accounting for a portion of the risk (Blaurock-Busch, Amin, & Rabah, 2011). Some researchers indicated that environmental influences likely play a role in the development of ASD (Blaurock-Busch et al., 2011). Research regarding the association of environmental influences and ASD has been underway for decades, but no research has identified a specific cause (Blaurock-Busch et al., 2011; Johnson, Giarelli, Lewis, & Rice, 2012; Naviaux et al., 2013). Previous researchers have focused on environmental influences of land and air (Roberts, English, Grether, Windham, Somberg & Wolff, 2007); Bornhag & Nanberg, 2010), but few researchers have examined geospatial distribution, rural and urban distribution, or variables as common as associations with water sources. Given that researchers believe that environmental sources account for a substantial portion of ASD risk, more exploratory research is needed.

A paucity of research surrounds the complex area of environmental interactions (Blaurock-Busch et al., 2011; Johnson et al., 2012; Naviaux et al., 2013). The National Institute of Health (NIH, 2009) reported that autism may be caused by gene damage in early fetal development because of environmental factors, and consider the condition multicausal (Blaurock-Busch et al., 2011). Deficiencies in some genetic elements result in decreased protective factors, which lead to increased susceptibility to toxins that can impair cognitive development and may lead to ASD (Blaurock-Busch et al., 2011). Blaurock-Busch, Amin, and Rabah (2011) asserted that ASD children may have a greater inability to detoxify environmental toxins which may result in neural damage. Such observation supports previous research indicating risk factors during in utero and in infancy neurodevelopment. Researchers who took samples from 2006 to 2008 from a psychiatric hospital in Saudi Arabia found children with ASD were more susceptible to environmental insults than neurologically typical controls (Blaurock-Busch et al., 2011). Additionally, researchers have found that the number of de-novo mutations is higher in ASD children with idiopathic and sporadic onset than in neurologically typical developing children (Johnson, Giarelli et al., 2012). Most copy number variation (CNV) mutations among ASD children are spontaneous and not inherited (Johnson et al., 2012). Copy number variation (CNV) is defined as the gene variation in the number of copies between individuals (NIH, 2015). In twin studies exploring causes of ASD, researchers indicated that genetic heritability and environmental factors play key roles in gene variation (Bauer & Kriebel, 2013; Yonan et al., 2003). Naviaux et al. (2013) also found that environmental factors and genetics are responsible for some types of ASD.

In summary, it is currently believed that no single gene or environmental influence can account for the development of ASD—its etiology remains highly likely to be heterogenic because of probable, yet undiscovered, gene-gene and gene-environment interactions (Johnson et al., 2013). Consequently, the evidence suggests that an examination of fundamental environmental factors may be a productive area for systematic research. Additionally, understanding the role of the environment on development of autism may have significant social change implications. These potential implications remain largely unexplored.

Statement of the Problem

Autism Spectrum Disorders are of great public health concern because ASD prevalence is rapidly increasing, and the cause of ASD is not understood. The epidemiology of autism and its prevention remains undefined. Autism is considered an epidemic in the United States and a pandemic on a global scale (Bateman, 2013). With autism diagnoses, researchers are struggling to understand the cause or causes of autism. Research on water sources as an environmental differentiator has not been carried out in any systematic way. Rigorous examination of city-sourced verses private-sourced water using factor analysis, Geographical Information Systems (GIS), and geospatial techniques to identify clusters has never been completed. Given the paucity of current research regarding water sources and health issues, there are a series of questions to investigate that give this study relevance and value.

Research Questions

This research explored the relationship between water source and the geospatial distribution of autism in Lane County, Oregon; specifically, whether there was a drinking water type associated with ASD cases in Lane County, Oregon. The following research questions were posed:

1. What is the association between city-provided and private-sourced water supply and the presence of ASD cases among persons aged 0–17 years in Lane County Developmental Disabilities Services between each zip code in Lane County, Oregon?

$H_0 1$: There is no association between city-provided and private-sourced water supply and presence of an ASD diagnosis among persons aged 0–17 years in Lane

County Developmental Disabilities Services in Oregon between each zip code in Lane County, Oregon.

H_a1: There is an association between city-provided and private-sourced water supply and presence of an ASD diagnosis among persons aged 0–17 years in Lane County Developmental Disabilities Services in Oregon between each zip code in Lane County, Oregon.

2. Are there any patterns or clusters either within a zip code or interacting with surrounding zip codes based upon number of households by drinking water source?

H_02: There are no clusters of ASD cases either within a zip code or interacting with surrounding zip codes based upon number of households by drinking water source.

H_a2: There are clusters of ASD cases either within a zip code or interacting with surrounding zip codes based upon number of households by drinking water source.

To answer these questions, data was obtained from Lane County using patient-level data from the Lane County Developmental Disabilities Services department for all persons aged 0–17 years currently receiving services. These data specifically consist of sociodemographic variables such as gender, age, comorbidities, race and ethnicity, place of birth, and water source. Other data used includes census data by zip code. This data will also characterize the study population.

Conceptual Framework

The Integrative Model of Environmental Health (IMEH) guided this study, which encompasses overlapping physiological, vulnerability, epistemological, and health protection domains and allows a comprehensive evaluation of environmental health issues (Dixon & Dixon, 2002). IMEH is important because the model is grounded in medical principles and is based upon the idea that environmental toxins, including what we eat and drink, affect our health. With regard to this particular study of water source and ASD, IMEH allows us to consider water source in the context of being an exposure agent. The model allows us to determine environmental exposures, which people are negatively affected by exposures, how the population views exposures, and what can be done to address environmental exposures. If patterns of autism are found to correlate with water source, then IMEH will enable us to characterize pathways, inform the public, and change policy. If no relationships are found, then IMEH enables us to communicate next steps and direct research to other potential exposures leading to the development of ASD.

In the IMEH model, there are four domains: physiological, vulnerability, epistemological, and health protection (Dixon & Dixon, 2002). The physiological domain begins the exposure review process and identifies agents, exposures, bioaccumulation, and health outcomes (Polivka, Chaudry, Crawford, Wilson, & Galos, 2012). *Exposure* is defined as contact made between a chemical, physical, or biological agent and the outer boundary of an organism (Dixon & Dixon, 2002). Exposure is quantified as "the amount of an agent available at the exchange boundaries of the organism (e.g., skin, lungs, gut) by intersecting the stressor and the receptor in both space and time" (Environmental Protection Agency (EPA), 2014, p. 1).

Vulnerability is related to exposure within the scientific community and essentially refers to susceptibility to harm (Turner et al., 2003). Vulnerability is assessed through individual and community characteristics (Dixon & Dixon, 2002), is interpreted many ways, and represents a conceptual cluster for integrative human-environment research (Fussel, 2006). Vulnerability factors include susceptibility and sensitivity in regards to genetic, life, and disease status (Dixon & Dixon, 2002). *Differential exposure* refers to proximity to and sources of pollutants; *differential preparedness* refers to the level and ability to respond to exposure, and a differential ability to recover (EPA, 2013).

The epistemological domain encompasses personal thought and social knowledge—how each individual came to understand the environmental threats (Dixon & Dixon, 2002). It seeks to understand the beliefs and experiences of the target population (Dixon & Dixon, 2002). Last is the domain of health protection, which encompasses concerns, efficacy of response/treatment, and actions (Dixon & Dixon, 2002). This domain seeks to learn how the target population can protect themselves from the environmental exposure. However, the addition of a domain prior to the physiological domain has been suggested in order to stress the importance of prevention, or decrement of exposure (Polivka et al., 2012). Additionally, in 2010, Perron and Oal (as cited by Polivka et al., 2012) came to understand the environmental threats and suggested the model also include components to address secondary and tertiary care. This model allows researchers to evaluate environmental health issues (Dixon & Dixon, 2002).

An example application of the IMEH framework is the current study led by the National Center for Global Health & Medicine (NCGM). The NCGM study is using location specific geospatial analysis to explore ASD and the associations between potential environmental insults and assumed social stressors, such as low economic and social status experienced by the mother during preconception, pregnancy, and the early years of the child's life (Progressive Tech Federal System, Inc. (PTFS), 2014). Researchers hope to begin identifying patterns that lead to the development of ASD.

Nature of the Study

The purpose of this study was to examine the association between drinking water sources and ASD in Lane County, OR. The study included secondary data obtained from Lane County Developmental Disabilities Services in Oregon of all open ASD cases during the month of April 2014 served by Lane County Developmental Services department; therefore, data was retrospective in nature. This agency serves children and adults with developmental disabilities by providing case management, family support, crisis services, community-based employment and residential services, high school transition coordination, adult protective services, and child and adult foster care (Lane County Developmental Disabilities Services, n.d.). Their goal is to support opportunities for independence and self-determination of the population they serve (Lane County Developmental Disabilities Services, n.d.). They collect data to assist in determining eligibility for services by obtaining information related to medical history, contact information, parent perception of diagnosis, and academic activities of daily living functioning (Lane County Developmental Disabilities Services, n.d.). This agency provides many services to improve the lives of individuals with developmental disabilities.

The study population consisted of children aged 0–17 years with a current ASD diagnosis who were currently receiving services through their county's developmental disabilities services department. Variables collected included gender, current living situation (residing with biological, adoptive, or foster parents), special education status (whether they are on an Individual Evaluation Plan), comorbidities (e.g., intellectual disabilities, syndromes, physical health, or mental health conditions), birth year and place, race, ethnicity, zip code, and drinking water source (private- vs. city-sourced).

Assumptions

For this study, several assumptions were made. All open ASD cases during the month of April 2014 served by Lane County Developmental Services department were identified and used in this study. Assumptions include that data collected by Lane County Development Disabilities Services were correct and as complete as possible based upon the intake interview, medical records, and parent feedback. Additionally, it was assumed that participants reflected a fairly representative sample of the ASD population in Lane County, Oregon.

Scope and Delimitations

The geographical location of the study was Lane County, Oregon. The target population was persons with ASD receiving services from Lane County Developmental Disabilities Services Department for persons aged 0–17 years as of April 2014. This avoided short-term changes and their effects, but the data collection tool used by Lane County likely changed over the years. Data collected for this study were limited to participants' files, which were provided by the agency in confidential, de-identified form in an Excel spreadsheet stored electronically on a password protected computer allowing access to only one researcher. Data will be retained for 7 years. Additionally, data collection was limited to only participants receiving services, thereby potentially creating a selection effect. External validity was minimized as the results of the study were not generalizable to ASD populations other than those being serviced by Lane County Developmental Disabilities Services.

Limitations

A number of limitations of this study need to be noted. First, because this is an associational study, a cause and effect relationship between ASD and drinking water cannot be established, only exploration of associations and patterns can be postulated and explored. Categorical associations were utilized for direction and strength, which subsequently may influence future research (Creswell, 2009). The study setting was limited to Lane County, Oregon so results may not be generalizable to other areas. Additionally, it is impossible to control for all potential confounding elements which are common in ecological approaches within observational studies. Potential confounding elements include misclassification of exposure and inability to control for or differentiate between environmental exposures. Moreover, there is no environmental data and many of the suspected chemicals, such as endocrine disrupting compounds, do not have water exposure limits because they are not a priority pollutant (Oregon Health Authority, Drinking Water, n.d.). Additionally, secondary data was used—drinking water consumed by the child during the study may not be the same as that consumed in utero or during earlier childhood. There may be coding errors, and capturing every case was not feasible as some ASD families may not seek services through Lane County Developmental Disabilities Services. There are potential variances due to consumption of bottled water, other filtration systems, and the quality of the plumbing used to transport drinking water.

Furthermore, it is reasonable to assume that populations may be exposed to both sources of water during day-to-day activities. A presumption was made that primary residence water source was the most important exposure source—a point that is reasonable but uncertain. Therefore, results of this study may not find an association.

Significance

Although researchers studying persons with idiopathic autism suggested environmental exposures in utero for the majority of cases, the specific cause of autism remains unknown. Researchers also supported the hypothesis that idiopathic autism may be heritable (Muhle, Trentacoste, & Rapin, 2004), giving further concern for potential increase in prevalence. With the high prevalence of ASD in most developed countries, there is a debate over whether autism is a pandemic of modern culture (Bilbo, Nevison, & Parker, 2015). Most researchers have focused on air-borne sources (Bornehag & Nanberg, 2010), with some considering water sources as a potential source of association. Given the paucity of current research regarding water sources and health issues, researching water sources as an environmental differentiator is warranted. Understanding the role of the environment on autism in order to prevent or minimize the development of ASD would have significant implications and impact regarding interventions.

Social Change Implications

Understanding the role of the environment on autism can have significant social change implications. The quality of life for individuals with an ASD and their families may be improved by health, employment opportunities, and social independence (Jozefiak, Larsson, Wichstrom, Wallander, & Mattejat, 2010). In the U.S., young adults with ASD have the highest rate of unemployment over any other disability group, including intellectual disability (Shattuck et al., 2012). This unemployment can subsequently result in lifetime support from family or social service agencies. Their overall future is similar to African-American youths from lower SES (Shattuck et al., 2012). It is important to examine how to prevent this disorder due to the low rates of employment, independent living, and quality of life in affected populations, not to mention the emotional and financial toll on families, service providers, and the educational system.

Research which connects ASD to environmental factors and informs policy makers may ultimately lessen the costs to families and agencies that provide services to this population, and may prevent unemployment and underemployment for people with ASD by preventing exposures that contribute to the development of ASD. In this research study the geospatial distribution of autism in Lane County, Oregon, was explored. The findings of this study, combined with previous research, may provide more evidence that environmental influences contribute to autism risk.

Definitions

Medical Terms

Autism: "A developmental disorder that appears in the first 3 years of life, and affects the brain's normal development of social and communications skills" (U.S. National Library of Medicine, 2014, p. 1).

Autism Spectrum Disorder (ASD): The American Psychiatric Association's (2013) Diagnostic and Statistical Manual, fifth edition (DSM-5) provides standardized criteria to help diagnose ASD. People with ASD tend to have communication deficits, such as responding inappropriately in conversations, misreading nonverbal interactions, or having difficulty building friendships appropriate to their age (American Psychiatric Association, 2013a). In addition, people with ASD may be overly dependent on routines, highly sensitive to changes in their environment, or intensely focused on inappropriate items (American Psychiatric Association, 2013a). Again, the symptoms of people with ASD will fall on a continuum, with some individuals showing mild symptoms and others having much more severe symptoms. This spectrum will allow clinicians to account for the variations in symptoms and behaviors from person to person (American Psychiatric Association, 2013a).

Asperger's Syndrome: The latest DSM-5 no longer uses this term; however, the term is frequently used in previous research. It is delineated by the following characteristics:

1. Qualitative impairment in social interaction, as manifested by at least two of the following: (a) Marked impairments in the use of multiple nonverbal behaviors such as eye-to-eye gaze, facial expression, body posture, and gestures to regulate social interaction. (b) Failure to develop peer relationships appropriate to developmental level. (c) A lack of spontaneous seeking to share enjoyment, interest or achievements with other people, (e.g., by a lack of showing, bringing, or pointing out objects of interest to other people). (d) Lack of social or emotional reciprocity.

2. Restricted repetitive and stereotyped patterns of behavior, interests and activities, as manifested by at least one of the following: (a) Encompassing preoccupation

with one or more stereotyped and restricted patterns of interest that is abnormal either in intensity or focus. (b) Apparently inflexible adherence to specific, nonfunctional routines or rituals. (c) Stereotyped and repetitive motor mannerisms (e.g., hand or finger flapping or twisting, or complex whole-body movements). (d) Persistent preoccupation with parts of objects. (DSM 5 cited by Autism Network International, 2013).

Social (Pragmatic) Communication Disorder (SCD): Per American Psychiatric Association (2013b), SCD is characterized by:

"A persistent difficulty with verbal and nonverbal communication that cannot be explained by low cognitive ability. Symptoms include difficulty in the acquisition and use of spoken and written language as well as problems with inappropriate responses in conversation. The disorder limits effective communication, social relationships, academic achievement, or occupational performance." (para 2).

Idiopathic: The cause of disease is of unknown origin (NIH, n.d.).

Pervasive Developmental Disorder (PDD): Within DSM-4, PDD encompassed autism, Rett syndrome, Asperger disorder, and childhood disintegrative disorder (CDD) (DMS-4, 1994).

Pervasive Developmental Disorder-Not Otherwise Specified (PDD-NOS): Severe and pervasive development of reciprocal social interaction associated with impairment in either verbal or nonverbal communication skills or with the presence of stereotyped behavior, interests, and activities, when criteria are not met for a specific PPD (DMS-4, 1994).

Phenotype: An organism's physical traits and characteristics (National Science

Foundation, 2011).

Teratogens: A substance, organism, or process that causes malformation in a fetus (National Institute of Health, n.d.).

Comorbidity Terms

The Lane County Developmental Services Department uses the following categories to define observed or previously diagnosed conditions upon intake and are reported by the intake worker or the parent. A health care provider later verifies these conditions. The following are broad definitions health care providers may use to diagnose a person.

Behavior Dysfunction: “Behavior Dysfunction. A disorder characterized by displayed behaviors over a long period of time which significantly deviate from socially acceptable norms for a person's age and situation” (McGraw-Hill Concise Dictionary of Modern Medicine, 2002, para. 1).

Cerebral Palsy: “Cerebral Palsy is a group of disorders that affect a person’s ability to move and maintain balance and posture” (CDC, 2015a).

Communication Dysfunction: Definded by the American Speech-Language-Hearing Association (1993) as:

> Impairment in the ability to receive, send, process, and comprehend concepts or verbal, nonverbal and graphic symbol systems. A communication disorder may be evident in the processes of hearing, language, and/or speech. A communication disorder may range in severity from mild to profound. It may be developmental or acquired. Individuals may demonstrate one or any combination of communication

> disorders. A communication disorder may result in a primary disability or it may be secondary to other disabilities (para. 2).

Emotional Problems: “Emotional disability is defined in psychiatry as behavior, emotional, and/or social impairment exhibited by a child or adolescent that consequently disrupts the child's or adolescent's academic and/or developmental progress, family, and/or interpersonal relationships” (McGraw-Hill Concise Dictionary of Modern Medicine, 2002, para. 3).

Fine Motor Dysfunction: A dysfunction of “coordination of muscles, bones, and nerves to produce small, precise movements” (Kimmel & Ratliff-Schaub, 2015, para. 1).

Gross Motor Dysfunction: “The acquisition and execution of coordinated motor skills is substantially below that expected given the individual’s chronological age and opportunity for skill learning and use” (American Psychiatric Association, 2013c, p. 307, para 4).

Hearing Dysfunction: “Hearing loss can be congenital or acquired, progressive or sudden, temporary or permanent, unilateral or bilateral, and mild or profound” (O'Neil, 2011, p. 1378).

Mental Illness: “A mental disorder is a syndrome characterized by clinically significant disturbance in an individual’s cognition, emotion regulation, or behavior that reflects a dysfunction in the psychological, biological, or developmental processes underlying mental functioning” (American Psychiatric Association, 2013c, p. 707).

Intellectual Disability: "A disorder with onset during the developmental period that includes both intellectual and adaptive functioning deficits in conceptual, social, and practical domains" (American Psychiatric Association, 2013c, p. 33).

Seizures or Epilepsy: "Consists of sudden synchronous high-frequency firing by localized groups of neurons in certain brain areas" (O'Neil, 2011, p. 1610).

Visual Dysfunction: "Distortion of vision is an inability to see clearly and correctly. This distortion may involve a poor focus due to a refractive error, lack of depth perception, double vision, glare or halos, flashes of light or floaters. It may also involve color blindness" (O'Neil, 2011, p. 1417).

Other Definitions

Integrated Model of Environmental Health (IMEH): A model developed by Jane Dixon and John Dixon in 2002. This model is used to evaluate environmental health issues and connects research findings with how populations understand and act upon the findings (Dixon & Dixon, 2002).

Lane County: Lane County is located in Oregon and consists of 4,620 square miles located midway within Oregon along the coastline (Lane County Oregon, n.d.).

Water Sources: In Eugene, city-provided water is surface-sourced from the McKenzie River and travels 800 miles to supply almost 200,000 customers with no history of violating any water quality standards (Eugene Water & Electricity Board (EWEB), n.d.). City-provided water in Springfield is ground-sourced from seven well fields accessing one aquifer and supplemented from surface-sourced water from the Middle Fork Willamette River. Water travels through 240 miles of piping to supply

56,000 plus consumers (Springfield Utility Board (SUB), 2015). The water is treated for organisms through chlorination for both cities. Private wells are only tested for arsenic, nitrates, and coliform bacteria (Oregon Health Authority, Well Testing, n.d.). Endocrine disrupting compounds (EDCs) are unregulated and untested in Oregon (Oregon Health Authority, Drinking Water, n.d.).

Zip Code: The United States Postal Service (USPS) zip codes are designed to identify delivery areas linked post offices or delivery stations serving those areas (U. S. Census Bureau, 2015).

See Appendix A for more definitions of terms and symbols used in this research.

Chapter 2: Literature Review

Overview

This chapter presents a review of the existing literature in the area of ASD incidence and water source. The history and definitions of autism, ASD, and comorbidities are presented.

Literature Search Strategy

The literature review supporting this study included a review of all peer reviewed publications from 2002 to 2014 through EBSCO and all major Internet search engines spanning those 12 years. Key search terms included *autism, Asperger's syndrome, high-functioning autism, comorbidities, phthalates, environmental exposures, water, Oregon, prenatal, plastic*, and *GIS* with an emphasis on studies which included water exposure analysis. This produced a total of 27 journal articles. Of these articles only one directly related to drinking water in Oregon and was selected for inclusion and discussion. There is little research specific to a geographical study of autism and water sources in the U.S.

Autism Definition and History

Autism is a complex neurological disorder with a diverse presentation (Kumar et al., 2011) and multiple etiologies with long-term ramifications (Andreica-săndică et al., 2011). Autism spectrum disorders (ASD) encompass impairments in many areas, such as communication, language, social skills, and restricted interests. Autism was first discovered by Kanner in 1943, who believed it was an early form of schizophrenia. Later, in 1980, it was classified as a developmental disorder (Johnson et al., 2012). The name Asperger's syndrome was added to the DSM-4 in 1987 (Johnson et al., 2012) but was removed in the DSM-5 and changed to ASD in 2013 (Buxbaum & Baron-Cohen, 2013). As of 2013, three domains relate to ASD deficits: social interaction, social communication, and presence of repetitive behaviors and interests (Cohen et al., 2013). However, it is the deficits in social interaction and communication that are the hallmark of ASD (Cohen et al., 2013). Presentation is highly heterogeneous, but symptom onset often occurs before age three (Cohen et al., 2013). Early infancy symptoms can include atypical ability to imitate, detach, and respond to name (Cohen et al., 2013). Infants may also display atypical ability to read body language and make eye contact, often accompanied by delayed speech and limited interests (Cohen et al., 2013). These symptoms are typically noticed between 18 and 36 months of age (Cohen et al., 2013).

The Diagnostic and Statistical Manual of Mental Disorders (DSM-5) significantly changed the way individuals are diagnosed with autism, placing an increased focus on the social-communication domain (Buxbaum & Baron-Cohen, 2013). The DSM-5 also underscores the broad category of autism spectrum disorder (ASD) by removing the previous subcategories of Asperger's syndrome (AS) and pervasive developmental disorders (PDD) (Buxbaum & Baron-Cohen, 2013). The new DSM-5 changes are likely to pose ongoing challenges in longitudinal studies because of a decreasing ability for higher functioning populations to meet diagnostic criteria; this will result in the potential loss of support services and Asperger's syndrome (AS) identity (Buxbaum & Baron-Cohen, 2013). The decrease in services may increase suicide rates, as depression is a common comorbidity for higher functioning populations (Buxbaum & Baron-Cohen, 2013). Although prevalence of ASD has increased 10 times using new diagnostic criteria since May 2013, this does not reflect an actual increase in risk, but rather it reflects broader diagnosis criteria (Johnson et al., 2012).

Researchers studying ASD diagnosis have focused on genomics and observable behaviors from gene-environment interactions known as phenotypes (Johnson et al., 2012). A study conducted by Naviaux et al. (2013) using mice models found antipurinergic therapy with suramin corrected multisystem comorbidities in 16 phenotypes commonly found in ASD cases, such as social abnormalities. Unfortunately, this type of therapy is not suitable for long term use in humans because of its toxicity, but the authors asserted it may assist in pharmacological development for the treatment of symptoms in ASD, and may contribute to a better understanding of pathogenesis (Naviaux et al., 2013). In studies using neuroimaging, researchers found brain connectivity dysfunction in ASD cases, indicating a possible cause of atypical behaviors (Aoki, Abe, Nippashi, & Yamasue, 2013). Researchers studying postmortem brains found long-distance under-connectivity (Aoki et al., 2013). This research indicated that use of neuroimaging may provide a possible means of accurate and early detection of ASD.

Global Prevalence

Globally, the prevalence of ASD has increased rapidly during the last decade, as it did in the United States. The Centers for Disease Control and Prevention (CDC) reported that one in 50 U.S. school children are diagnosed with autism (CDC, 2013). Autism is almost five times more common in boys than in girls (CDC, 2015) and it is estimated that one in 31 boys and one in 143 girls are affected (Talk About Curing Autism, 2013). Of note, the ratio of affected boys to girls is consistent between countries (Johnson et al., 2012). South Korea and other areas of Europe and North America have reported a 2.6% ASD prevalence (Johnson et al., 2012; Andreica-săndică et al., 2011).

In 2010, Miles, McCathren, Sticher, and Shinawi found that 50–70% of children with ASD had intellectual disabilities, but approximately 30% had normal development until 1.5 to 2 years of age. Autism is the second most common serious developmental disability after mental retardation or intellectual impairment (CDC, 2015). Around 20–25% of ASD cases are associated with genetics and 75–80% are idiopathic (Miles et al., 2010). However, in twin and family studies, heritability was found to be more than 90% (Miles et al., 2010). Because the majority of ASD cases are idiopathic, have a high inheritance potential, and lack a known cure, the global prevalence of autism is considered a worldwide epidemic (Kang et al., 2013). Previous researchers found an increase in autism prevalence in higher socioeconomic status (St-Hilaire, Ezike, Stryhn, & Thomas, 2012).

Etiology

The etiology of most ASD cases remains unknown, with only 1–2% being accounted for by genetic syndromes, de novo copy number variants, and defined mutations (Ashwood et al., 2011). Although a definitive cause for autism has not been discovered, researchers indicated multifactorial influences, such as large gene and environmental interactions during prenatal development (St-Hilaire et al., 2012). Research regarding the association of environmental influences and ASD has been underway for decades, but researchers have not identified a specific cause. Many researchers believe the causes of ASD are multifaceted, with genetics only partially accounting for the risk, and environmental influences likely playing a role in the development of ASD (St-Hilaire et al., 2012). With genetics only responsible for a small part in the development of ASD, studying environmental factors is essential. Previous researchers have studied environmental influences of land and air, but few have examined water sources, and none have compared city-provided and private-sourced water in a systematic way. Considering that researchers such as Naviaux et al. (2013) and Yonan et al. (2003) found that environmental sources account for some risk of ASD, examining drinking water as a potential differentiator is important.

Comorbidities

Autism spectrum disorder is a complex neurological disorder with a diverse presentation of long-term side-effects (Kumar et al., 2011). It is the second most common serious developmental disability after mental retardation and intellectual impairment (CDC, n.d.). Fifty percent or more of the children with ASD have intellectual disabilities and approximately 30% of them will have normal development until between 18 months and 2 years of age (Miles et al., 2010). Moreover, about 75% of this population with ASD has comorbidities such as depression or anxiety (Mukkaddes, Herguner, & Tanidir, 2010). Other common comorbidities include sex chromosome trisomies, such as XYY and Klinefelter syndrome (XXY), and other syndromes such as Fragile X, Rett syndrome, tuberous sclerosis, Smith Magenis, Angelman syndrome, Prader-Willi syndrome, Smith-Lemli-Opitz syndrome, and velocardiofacial syndrome (Johnson et al., 2012). In a meta-analysis, Anitha et al. (2012) found that developmental regression, seizures, gastrointestinal dysfunction, and motor dysfunction were present in ASD cases with atypical mitochondrial dysfunction. Additionally, studies have shown that people with ASD can have increased immune system dysfunction, contributing to specific behavior symptomology (Ashwood et al., 2011).

Stereotypic and repetitive behaviors commonly present in the ASD population result from inhibition deficits, which can also lead to challenges in planning and self-control (Pooragha, Kafi, & Sotodeh, 2013). Frontal lobe deficits in neurobiological processing result in executive functioning (EF) difficulties and explain cognition difficulties present in ASD populations; however, it is not clear if frontal lobe deficit is a primary or secondary cause of autism (Pooragha et al., 2013). Executive functioning (EF) disorder contributes to difficulties in functioning in daily life skills, social interaction, and self-preservation (Pooragha et al., 2013). Moreover, the social impairments contribute to depression and anxiety found in approximately 77% of this population (Mukkaddes et al., 2010). This rate is alarming when compared to a much lower lifetime incidence of depression in the general population of approximately 13% to 17% (Rosenquist et al., 2011).

Researchers also found genes and copy-number variation (CNV) abnormalities in 20% of ASD cases (Naviaux et al., 2013). Conversely, Fatemi et al. (2013) cited 50 genes or gene variants to account for 30% of ASD cases. Overall, shared autistic traits are found in 2% to 8% of sibling studies (Johnson et al., 2012). However, researchers found shared autistic traits in 60% to 90% of identical twin studies compared to 0% to 10% of fraternal twin studies, indicating strong correlation with genetic causes (Johnson et al., 2012). Although mitochondrial dysfunction (MtD) has been associated with ASD, researchers have only detected MtD in 5% of ASD cases (Anitha et al., 2012). Additionally, Johnson, Giarelli, Lewis, and Rice (2012) confirmed that the number of de novo mutations was higher in ASD children with idiopathic and sporadic onset than in neurologically typical developing children. Most CNV mutations among ASD children are found to be spontaneous and not inherited (Johnson et al., 2012).

ASD studies have shown synapse formation and brain circuitry dysfunction in populations possessing responsible gene mutations (Menashe, Grange, Larsen, Banerjee-Basu, & Mitra, 2013). Studies regarding postmortem brains of autistic children and adults have shown abnormal neuropathologic characteristics, such as macrocephaly, and volumetric and cellular disorganization of the frontal cortex, parietal cortex, limbic structures, cerebellum, and cortical minicolumn (Fatemi et al., 2013). Menashe et al. (2013) asserted that over-expressed candidate genes in the cerebellar cortex are associated with the ASD etiology. In human and mouse general studies, the cerebral cortex affected cognitive and emotional processing, and regions within the cerebellum affected motor and cognitive tasks (Menashe et al., 2013). In a study of siblings conducted by Hu et al. (2009), the authors found higher testosterone levels in the sibling with autism than in the neurologically typical developing sibling. Women with congenital adrenal hyperplasia have elevated testosterone levels and often times these women also exhibit impaired social behavior similar to people with autism (Hu et al., 2009). These findings suggest that most ASD cases may result from gene and environmental interactions.

Prenatal and Early Childhood Environmental Exposures

Researchers believe childhood environmental exposures are related to later development of ASD (Clark et al., 2006). Hu et al. (2009) suspected that epigenetic and environmental triggers occur in the development of ASD, given that the ASD population has 10 times more copy-number variations. Many researchers have examined possible ASD causes such as various environmental pollutants, artificial insemination, age of the mother, maternal viral infection, maternal stress, and histone methylation dysfunction (Bauer & Kriebel, 2013, Bornehag & Nanberg, 2009, Hu et al., 2009; Larsson, Weiss, Janson, Sundell & Bornehag, 2009). Researchers have also examined specific gene damage, such as to FN2, GABR, OXTR, RELN, and SLC6A4, as well as chromosomal damage to chromosomes 2, 3, 15, 16, 17, and 22. Finally, researchers examined several copy number variants (Johnson et al., 2012). Researchers have identified suspected genes that play a role in ASD (NIH, 2009); however, environmental insults can put a susceptible person at-risk of developing autism (McAuley et al., 2012). The National Institute of Health (NIH, 2009) reported that environmental damage to genes in early fetal development may cause autism, and researchers consider the condition multicausal (Blaurock-Busch et al., 2011). Yonan et al. (2003) asserted that there are multiple gene variations that respond to environmental insults, which cause gene dysfunction. Researchers explored causes of ASD and found gene variation is influenced by genetic heritability (Bauer & Kriebel, 2013) and environmental factors (Yonan et al., 2003). Naviaux et al. (2013) also found that environmental factors and genetics are responsible for some types of ASDs. Currently, no single gene or environmental influence can account for the development of ASD—its etiology remains highly heterogenic, likely because of gene-gene and gene-environment interactions (Johnson, Giarelli, Lewis, & Rice, 2012).

In 2012, St-Hilaire, Ezike, Stryhn, and Thomas conducted an ecological study in the Pacific Northwest examining county prevalence rates of autism and environmental pollutants from surface-sourced drinking water and found precipitation was associated with meteorological factors in warm areas. The researchers further asserted that surface-sourced water was a possible vector of exposure to environmental contaminants and hypothesized that the trace levels of psychiatric pharmaceuticals found in surface-sourced drinking water could be a possible environmental contaminant associated with autism rates (St-Hilaire et al., 2012). However, a thorough comparison of city-sourced and private-sourced water has not been completed. In this study, the association of drinking water sources and autism rates were explored by applying a geospatial analysis.

Short-, Medium-, and Long-Term Concerns

Ahmedani and Hock (2012) discovered that children with autism and common psychiatric comorbidities found in 87–95% of the ASD population have overall poorer health outcomes and are less likely to have health insurance. Additionally, researchers reported that children and adolescents with autism have significantly lower quality of life (QoL), as reported by both the child and parent, than do neurologically typical developing peers (Jozefiak et al., 2010). Moreover, approximately 48,000 adolescents within the United States turn 18 years old each year with limited ability to obtain employment and live independently (Shattuck et al., 2011). Miles, McCathren, Sticher, and Shinawi (2010) projected that 75% of those teenagers will require social, academic, or parental support throughout their lifetime (Miles et al., 2010). Most individuals with ASD remain dependent upon their families and are socially isolated with marked social impairment throughout their entire lives (Vanbergeijk et al., 2008). Eaves and Ho (2008) found that 56% still lived with their parents and 35% lived in a supported residential situation such as a foster or group home. Only 8% of the participants lived fairly independently, defined as semi-sheltered or still at home with significant autonomy. Shattuck et al. (2011) noted that during the next decade, almost half a million children with ASD will become adults.

Water in Lane County, Oregon

City-Provided and Private-Sourced Water

In Eugene, city-provided water is surface-sourced from the McKenzie River (EWEB, n.d.) and city-provided water in Springfield is ground-sourced from seven well fields and the Middle Fork of the Willamette River (SUB, 2015). The water is treated for organisms through chlorination. Private wells must be tested before selling the property; however, the wells are only tested for arsenic, nitrates, and coliform bacteria (Oregon Health Authority, Well Testing, n.d.). Although the Oregon Health Authority (OHA) recognizes endocrine disrupting compounds (EDCs) as potential threats to human health, EDC levels are unregulated and untested (Oregon Health Authority, Drinking Water, n.d.).

Building Codes and Polyvinyl Chloride (PVC)

According to Oregon Administrative Rules 690-210-0290, well pipeliners must be made of steel or polymerized vinyl chloride (PVC) type 1220 or 1120 and SDR 26 (Class 160) or greater wall thickness (Oregon Administrative Rules, 2014). Lane County adheres to Oregon Plumbing Specialty Code requiring PVC, Acrylonite Butadine Styrene (ABS), and Polyethylene (PE) for water supply piping (Oregon Administrative Rules, 2014).

Water Consumption

The Oregon Health Authority, Drinking Water Division (n.d.), estimated that approximately 20 to 50 liters (5.3 to 13.2 gallons) of water are required per day for drinking, cooking, and personal cleaning per person in Oregon. According to the United States Census Bureau (2015), Lane County is the largest county in the state of Oregon, encompassing approximately 4,553 square miles of the approximately 95,988 square miles in the state of Oregon. Lane County encompasses 44 different zip codes and approximately 77 people per square mile (see Appendix B). Although the Portland area counties are more populated, Lane County is a larger geographical area. See Appendix C for the location and a visualization of approximate size of the 44 zip codes in Lane County (Mapscales.com 2014).

Demographic differences between Springfield and Eugene. There are more people under 65 with a disability living in Springfield than in Eugene (U. S. Census Bureau, 2014). Additionally, the educational level and cost of living in Springfield are lower than in Eugene (U. S. Census Bureau, 2014). Table 2 shows demographic data for Springfield and Eugene (U. S. Census Bureau, 2014).

Table 2

Demographical Differences between Springfield and Eugene

Demographic	**Springfield**	**Eugene**
Any Disability <age 65	13%	8.7%
High School Graduate	87%	94%
Bachelor's Degree	15%	39%
Hispanic/Latino	12%	8%
Language Spoken at Home other than English	10%	12%
Median Home Value	$168,600	$238,700
Per Capita Income	$19,703	$26,017

Summary

In summary, the literature review supporting this study included an examination of all scholarly publications from 2002 to 2014, with an emphasis on studies which included water exposure analysis. Of the 27 journal articles examined, only one of these articles directly related to drinking water and was selected for inclusion and discussion. This ecological study suggested environmental pollutants in surface-sourced drinking water and precipitation was associated with autism prevalence in several U.S. states. However, a thorough comparison of city-sourced and private-sourced water had not been completed. In summary, there is little research specific to a geographical study of autism and water sources, suggesting that additional systematic research will add to the body of scientific knowledge.

Chapter 3: Research Method

Purpose of the Study

The purpose of this research was to explore the relationship of water source and ASD prevalence in Lane County, Oregon, in order to examine, study, and characterize autism cases among children in Lane County, Oregon, utilizing patient-level data from the Lane County Developmental Disabilities Services Department with particular attention to their source of water supply. Additionally, geographical information systems aided by cluster analysis were utilized to generate risk maps in order to look for clusters and possible exposures.

This investigation also characterized cases and explored trends in sociodemographic variables such as gender, age, comorbidities, race and ethnicity, birth place, and water source. Research compared descriptive statistics for each variable, such as frequency tables and percentage rates. Additionally, sociodemographic variables allow a comparison to national data. Zip code data on each case was also collected to identify clusters. Census data by zip code provided demographic information.

Research Questions

1. What is the association between city-provided and private-sourced water supply and the presence of ASD cases among persons aged 0–17 years in Lane County Developmental Disabilities Services between each zip code in Lane County, Oregon?

$H_0 1$: There is no association between city-provided and private-sourced water supply and presence of an ASD diagnosis among persons aged 0–17 years in Lane

County Developmental Disabilities Services in Oregon between each zip code in Lane County, Oregon.

H_a1: There is an association between city-provided and private-sourced water supply and presence of an ASD diagnosis among persons aged 0–17 years in Lane County Developmental Disabilities Services in Oregon between each zip code in Lane County, Oregon.

2. Are there any patterns or clusters either within a zip code or interacting with surrounding zip codes based upon number of households by drinking water source?

H_02: There are no clusters of ASD cases either within a zip code or interacting with surrounding zip codes based upon number of households by drinking water source.

H_a2: There are clusters of ASD cases either within a zip code or interacting with surrounding zip codes based upon number of households by drinking water source.

Research Design

Little is known about water source and the prevalence of and risk factors for autism within specified geographic areas. This study is descriptive and exploratory, and serves as a preliminary study for further research. To contribute knowledge to this area, a cross-sectional approach was selected. A cross-sectional study is descriptive in nature, and is a snapshot of the situation where prevalence of characteristics can be described in terms of frequencies within the target population (Creswell, 2009). This design enables the simultaneous comparison of different variables, such as age, gender, comorbidities, and water source. However, causal inferences cannot be made with this type of design, as it is impossible to control or reliably analyze temporal variables that contribute to the cross-sectional "snapshot."

In this case, the primary exposure variable was either private-sourced water or city-sourced water. Private-sourced water is not required to be tested and treated routinely, whereas city-sourced water is treated and monitored (Oregon Health Authority, Drinking Water Division, (n.d.). The cross-sectional study design was chosen so that multiple hypotheses could be tested using secondary data at a specific point in time. This approach can be effective for a descriptive and exploratory study, as it provides a good quantity of interrelated data. However, time, cost, and access to primary data can limit this type of study design. It is noted that cross-sectional designs require larger sample sizes to detect differences within a subgroup population, and also that a temporal sequence of cause and effect cannot be determined (Levin, 2006; Creswell, 2009).

The null hypothesis asserts the independence of and lack of relationship to the variables. It is represented as H_0, e.g. $H_0: p = 0.05$. In this instance, the research questions were constructed to test the associational strength between water source and each dependent variable associated with ASD. The nature of the data available from Lane County led the researcher to use the chi-square statistical method to test the associational null hypotheses. The chi-square statistical method tests for association between two categorical variables such as gender, comorbidities, or prenatal exposure to drugs (Creswell, 2009). Contingency tables provide variable frequency distribution and can provide information on the interrelationship and interaction between two variables from a single population to test a null hypothesis. The estimates are non-directional and this test is only valid if the cell frequencies are equal to or greater than five. The details of the analyses are described in the data analysis section below.

Population

The target population was persons aged 0–17 years qualifying for services through Lane County Developmental Disabilities Services in April 2014. Data was obtained on a total of 276 persons with autism, based on inclusion and exclusion criteria. Inclusion criteria were open cases during April 2014 with a diagnosis of ASD. Exclusion criteria were birth outside of Lane County, Oregon, or a documented pre-natal exposure to drugs or alcohol. Additionally, cases were excluded if the persons were adopted or were currently in foster care, as their current address was not likely to be the address where that person lived when in utero.

Data Source Descriptions

Patient-level data was obtained from the State of Oregon, Department of Human Services, Lane County Developmental Disabilities Services; this data was on persons currently receiving services through the department. Information was provided in a MS Excel document. Specific variables included birth year, race, ethnicity, numerical address (coded for water source), zip code, place of birth, gender, pre-natal exposure, and comorbidities at intake. Written permission to gather data from Lane County Developmental Disabilities Services was obtained (see Appendix D).

The total number of private wells in Lane County was obtained from the Lane County Water Department, and data was available to the public. The number of households using city-provided water per zip code was compared. A description of the data analysis is described in the section below.

Data Collection Procedures

Lane County Developmental Disabilities Services collected data from original intake forms from all cases with an ASD diagnosis. The eligibility specialist at Lane County Developmental Disabilities Services completed these intake forms when meeting with the family and reviewing medical records. For this study, data from the original intake forms was obtained and entered into an Excel spreadsheet. Cases were identified by number and no personal identifying information was shared. Participants were only identified if they were accepted into services; sampling did not include individuals with ASD who did not seek or were not accepted for services.

Protection of Human Subjects

This study posed minimal risks to participants, as no personal identifying information, only secondary data, was shared. Walden University Institutional Review Board provided an ethical oversight of the study. The IRB approval number for this study is 03-05-15-0083616. In addition, a letter of cooperation and data use agreement from Lane County Developmental Services was obtained (Appendix D). All requirements were met to protect human subjects.

Secondary Data Analysis Concerns

Concerns when using secondary data include: accuracy of reporting, documentation, and reliability issues in study population selection that may affect internal and external validity. For example, the answers to prenatal exposure to drugs and alcohol may not be reliable as the parent is self-reporting and may not answer accurately due to fear of legal repercussions or embarrassment.

Accuracy of reporting. Data variables for this study were created from the original intake application. However, the intake form has changed over the years and also may not have been completed in its entirety. Missing variables are best managed through statistical analyses or exclusion from the study.

Study population selection. Lane County Developmental Disabilities Services Department was selected because it is the largest, but not the most populated, geographical county in Oregon (U. S. Census Bureau, 2015) serving persons with developmental disabilities. However, not all families seek or qualify for services for their child with a developmental disability, for several reasons. This researcher surmises some families may have adequate natural supports (supports from family, friends, neighbors, etc.), may simply not know of the agency's existence, may not qualify, may not understand the services available or may not want outside help in fear of government involvement and oversight. Therefore, data used in this study may not reflect the general population of persons aged 0–17 years with ASD in Lane County, and thus cannot be generalized within or outside the county. However, the Lane County Developmental Disabilities Services Department serves more persons with developmental disabilities than any other agency within Lane County, and Lane County is the largest geographical county in the state of Oregon (U. S. Census Bureau, 2015). These factors strengthen the internal validity enough to allow thoughtful investigation and provide a basis for future exploration of the topic.

Sample Size

The population of Lane County is 353,697 for 2010 when all zip codes are totaled (U.S Census Bureau, 2012). Lane County holds approximately 9% of the state population of 3,930,065 (U.S Census Bureau, 2012). Lane County Developmental Disabilities Services serves approximately 500 persons aged 0–17 years with any developmental disability and 276 persons aged 0–17 years with ASD (U.S Census Bureau, 2015), representing approximately 55% of all persons served by Lane County Developmental Disabilities Services.

The CDC (2015) reported that 1 in 68 children aged 8 years and 1 in 50 aged 6 to 17 years have ASD, representing approximately 2% of the general population in the U.S. According to the U.S. Census Bureau projections for 2013, 19.1% of the population is aged 17 years or younger in Lane County, Oregon (U.S. Census Bureau, n.d.). Lane County population is estimated at 353,697 with approximately 6,756 persons aged 17 years or younger (U.S Census Bureau, 2015). Based on the CDC's national estimate of ASD rates, approximately 135 persons aged 0–17 years have ASD in Lane County. Lane County Developmental Disabilities Services reported they serve 276 persons aged 0–17 years with an ASD. This reflects that the prevalence of ASDs in Lane County is 4.1%, compared to 2% nationally. Moreover, this does not include children whose families did not seek services through Lane County Developmental Services Department. The sample size calculations for this study included an alpha of .05 and a power of .80. This was based on a Type II error rate of 20% (80% power) and a Type I error rate of 5% for each two-tailed test of condition. The .05 significance level is the 5% probability that the null hypothesis is falsely rejected. The .80 power is the odds of observing an effect when it occurs. These values assist in determining the sample size needed.

Confidence Interval

For this study, a confidence level of 95% was selected. The expected sample size for the study was 134 participants, based upon the CDC's data setting national prevalence rates at 2% of the national average, and a projected population of 6,718 people age 17 or younger in Lane County. This yields a 2.35 confidence interval, resulting in a sample size of 124. However, if an effect size of 48 is used with one tail, a 95% confidence level, and .80 power, the effective sample size is 110. Lane County's projected sample size was approximately 276; more than double what is needed for sufficient power.

Data Analysis

Exploratory and Descriptive Analysis Methods

The descriptive, or univariate, statistics for the variables (including mean, mode, median, and standard deviations) for all continuous variables were calculated. The standard deviation allows a measurement of variability and provides a reference point for the mean distribution and average distance from the mean (Frankfort-Nachmias & Nachmias, 2008). Researchers use bivariate analysis to explain causes and relationships. Cross tabulation was carried out to summarize categorical data into a contingency table. Chi-square tests were completed to calculate differences of proportions and to determine differences between the observed and expected frequencies. Odds ratio analyses were completed for measures of association using confidence intervals with unconditional logistic regression models, and for adjusting for matching factors and other potential confounding variables to test for statistical stability. Additionally, variables were stratified by age and gender. The categories for age were categories for age factors 0–4, 5–10, 11–14, and 15–17, representing pre-school, primary, elementary and high school ages.

A 95% confidence interval (CI) was used to test the null hypotheses of global spatial randomness. Calculations were made based on a Poisson distribution, intended to identify the most likely clusters considering the census data. This allowed for an evaluation between zip codes for further insight of risk areas providing cluster detection and risk mapping.

Managing Missing Data

The data provided by Lane County Developmental Disabilities Services had missing data, which either arose out of incomplete intake forms, changes in the intake form during the previous seventeen years, or errors in the data collection process. Missing data can result in bias in statistical analyses and must be managed to preserve statistical power. Researchers can handle missing data in several ways. A long-standing approach is to use dummy variables, but this can result in biased parameter estimates and is not recommended (Osborne, 2012). Researchers have also used data in its original form, and list-wise deletion or mean replacement. A recent approach to replace the missing data is to use software to guess the value through linear regression (Osborne, 2012).

This study excluded data on ethnicity and pre-natal exposure, as there were only 18 responses to self-reported pre-natal exposure to drugs and alcohol. Although ethnicity was reported in the results, it may be invalid due to significant missing data or unknown responses. This study also excluded the variable of receiving special education, as nearly all of the participants qualified for and received special education. Additionally, participants were excluded if born outside of Lane County, adopted, or in foster care.

Associational Hypothesis Testing

Chi-square was used to assess water sources with autism as the health outcome, based upon population and number of households within each zip code. With categorical data, chi-square analyses, and continuous variables, an independent *t*-test can identify the statistical significance of associations between ASD cases and potential risk factors.

Data used at the county-level cannot identify ASD patterns within a county, as it is too broad; therefore, data was collected and analyzed on a more detailed basis using zip codes. Zip codes are a convenient division of the assessed area and may reveal more geographical details of ASD patterns. It further divides the two main cities, Eugene and Springfield, which have different water sources, surface-sourced and primarily well-sourced, respectively. To visualize spatial patterns, Epi-info and mapping software was used. This public domain software was developed by the Centers for Disease Control and Prevention for public health practitioners and researchers to analyze epidemiological statistics, graphs, and maps (CDC, 2014).

Pattern and Spatial Analysis

This study began by collecting data at the county-level to identify currently open ASD cases served by Lane County Developmental Disabilities Services for a snapshot view. The data included currently open cases in April 2014, defined as persons aged 0–17 years with an ASD diagnosis who were currently receiving services from Lane County Developmental Disabilities Services. The variables collected include birth year, race, ethnicity, numerical address (coded for water source), zip code, place of birth, gender, pre-natal exposure, and comorbidities at intake. The data was sanitized by Lane County Developmental Disabilities Services department to prevent access to any personal identifying information regarding the cases.

Second, visualization of spatial patterns, identification of clusters, and potential areas of risk using Epi Info version 7 mapping software were conducted. Without visualization, it would be difficult to assess the proximity of higher incidence zip codes to each other or to higher risk areas such as refuse stations, industrial facilities, or other potentially high risk areas. The Epi Info software is widely used in the field of epidemiology for geospatial information. Area-based cluster analysis was used instead of point-based methods, as point-based methods would require exact location of individual occurrences, and this data was not available. The study produced risk maps using Epi Info software (Appendix C). Understanding the connection of space and time is a key area of concern when studying areas of risk when limited spatial data is available. Development of spatial models can improve understanding of associations between geographical areas and health outcomes (Gruenewald, 2013). Using spatial cluster analysis allowed researchers to take the initial step in investigating patterns of ASD, allowing for researchers to conduct more detailed analyses using retrospective cohort, cross-sectional, case-control, or observational methods (Gruenewald, 2013). Additionally, these models can help explain the contributions of socioeconomic forces and identify the influence of public health services provided to the target population. Accordingly, this study employed GIS as part of its exploratory strategy to establish and deepen apparent associations between water sources and ASD cases.

Summary

Standard Statistical Package for Social Sciences (SPSS) version 22 was used to analyze non-spatial data, and Epi Info version 7 software was used to analyze spatial data. Descriptive statistics were used to describe frequencies and overall characteristics. Results of the analysis were used to identify clusters that exceeded statistical significance. The null hypothesis of no clusters was rejected when a statistical significance at the > 0.05 level was met. In summary, the final study data set consisted of 91 cases. An exploratory analysis was conducted to review basic descriptive statistics. This was followed by specific hypothesis testing and then a visual spatial analysis using Epi Info version 7 mapping software. Results of these procedures are reviewed and summarized in the next chapter.

Chapter 4: Data Analysis and Findings

Overview and Purpose of the Study

This study explored cases of ASD among children in Lane County, Oregon, utilizing patient-level data from the Lane County Developmental Disabilities Services department. The purpose of this research was to explore the relationship of water source and ASD prevalence in Lane County, Oregon, in order to examine, study, and characterize autism cases among children in Lane County, Oregon, utilizing patient-level data. Patient-level data was obtained from the State of Oregon, Department of Human Services, Lane County Developmental Disabilities Services regarding persons with ASD aged 0–17 years receiving services in April 2014. Analysis of sociodemographic variables allowed for identification of trends.

Key Descriptive Findings

Overview of Cases and Variables

Comparisons using frequency tables and percentage rates were made for each variable. Descriptive, inferential, and mapping analyses were used to generate risk maps in order to look for incidence clusters according to water source by zip code. Zip code data on each case was used to identify and illustrate geospatial visual clusters based upon the 2000 U.S. Census Bureau population data. The study involved a total of 276 cases for persons aged 0–17 years with ASD. Data was provided by Lane County Developmental Disabilities services. Only 18 responses to self-reported pre-natal exposure to drugs and alcohol were obtained; therefore, the category was deleted and the case maintained. Special education is required if the child is age five or older; therefore almost every child in the study population received it, and thus this category was deleted. Persons who were adopted, in foster care, or born outside of Lane County were excluded, leaving 91 cases for the study.

Ethnic and Racial Categories

This data was obtained at the intake interview and the data represents the parents' characterization of their child's ethnicity and race. Ethnic categories include Hispanic or Latino, Non-Hispanic or Non-Latino, and unknown; however, the majority of the cases were listed as unknown in the analysis. Race categories include American Indian, Alaskan Native, Black, Native Hawaiian or other Pacific Islander, White, Asian, or unknown. The majority of the cases listed race as White. The data also denotes multi-racial participants.

Comorbidity Categories

Data on comorbidity was obtained at the intake interview from the parent and case worker based upon their perception and knowledge. Their responses may not be confirmed by a professional, but are rather the perceptions of the parent or case worker. Comorbidity analysis categories were coded by number for processing, and included: none (0), behavioral dysfunction (1), cerebral palsy (2), communication dysfunction (3), emotional problems (4), fine motor dysfunction (5), gross motor dysfunction (6), hearing dysfunction (7), mental illness (8), intellectual disability (ID) (9), seizures or epilepsy (10), visual dysfunction (11), and other (12). Detailed definitions for the comorbidity categories can be found in the glossary at the end of this chapter.

Water Source Categories

Water source information was obtained by residence zip code. Water was either city sourced or private sourced. Residence addresses and zip codes are coded for water source, providing the necessary information in conjunction with census data. This study aimed to explore the importance of water source to the etiology of autistic spectrum disorders.

Exploratory and Descriptive Analysis Findings

Frequencies and Percentages

The predicted hypotheses presented in Chapter 3 were explored using descriptive statistics, and tested using Chi-square, and the spatial analysis supported by Epi Info mapping. The alpha level was set at $p = .05$ for significant findings. Below are the percentages and frequencies of participant variables. Variables include gender, race, ethnicity and birth year. Percentages and frequencies are also provided for water source as an independent variable and comorbidities as possible dependent variables.

Gender. A total of 91 participants took part in the study. The majority of the participants were male (n = 73, 80%). This represents a ratio of 5 males to 1 female and is consistent with national and global ASD prevalence rates. Figure 1 displays the number of cases of autism by gender.

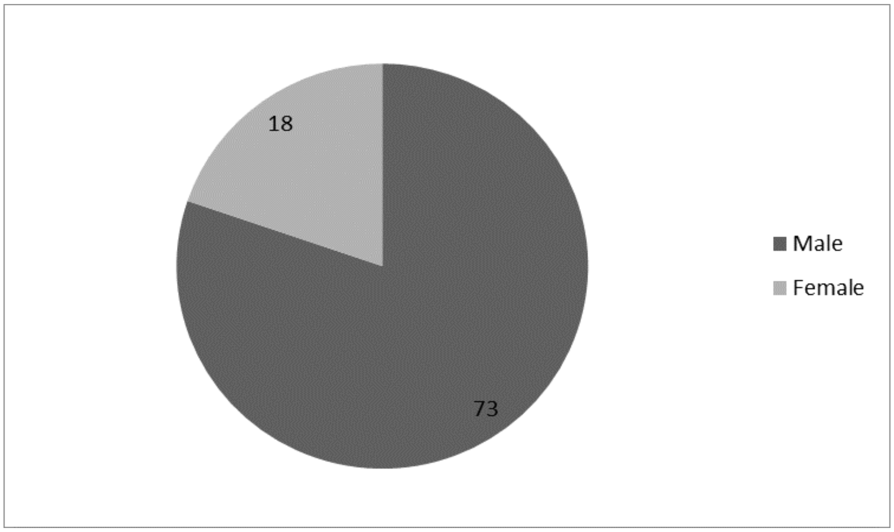

Figure 1. Number of cases of autism in Lane County, Oregon, by gender.

Race. The majority of participants fell into the category of White for race (n = 64, 70%). Whites represented 70% of the cases, compared to 90% for the Lane County overall general population (U.S Census Bureau, 2015). Multi-racial (n = 12, 13%) and Unknown (n = 13, 14%) may account for the low representation of Whites. Blacks accounted for 1% and this is consistent with the overall general population of Blacks in Lane County of 1% (U.S Census Bureau, 2015). Asians accounted for 2% compared to the overall general population in Lane County of 2.4%. Figure 2 displays the number of cases of autism by race.

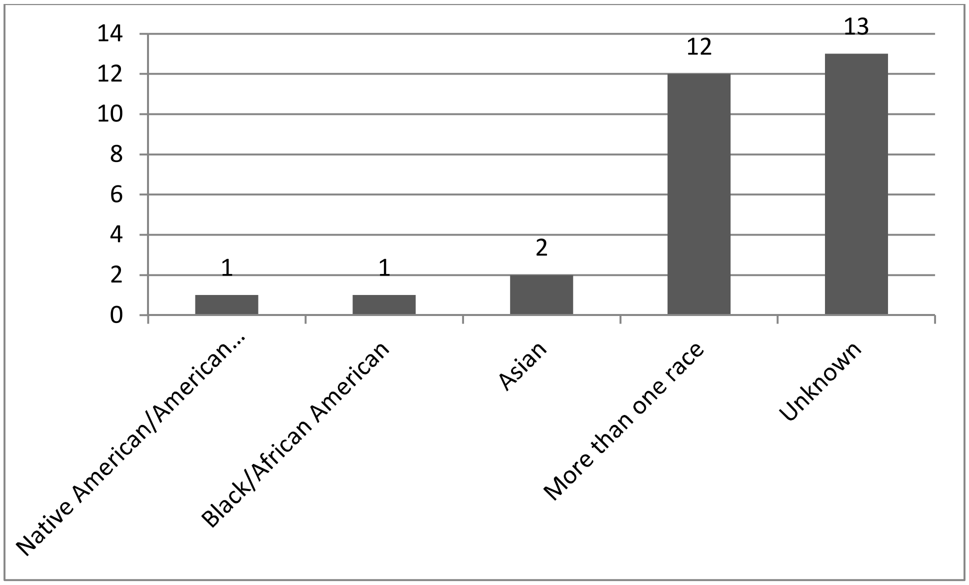

Figure 2. Number of cases of autism in Lane County, Oregon, by race.

Ethnicity. The majority of the participants selected Non-Hispanic (NH) for Ethnicity (n = 35, 39%). The remaining participants selected Hispanic (H) (n = 15, 16%) and Unknown (UK) (n = 41, 45%). This category may not provide valid information given the high number of responses of unknown. Figure 3 displays the number of cases of autism by ethnicity.

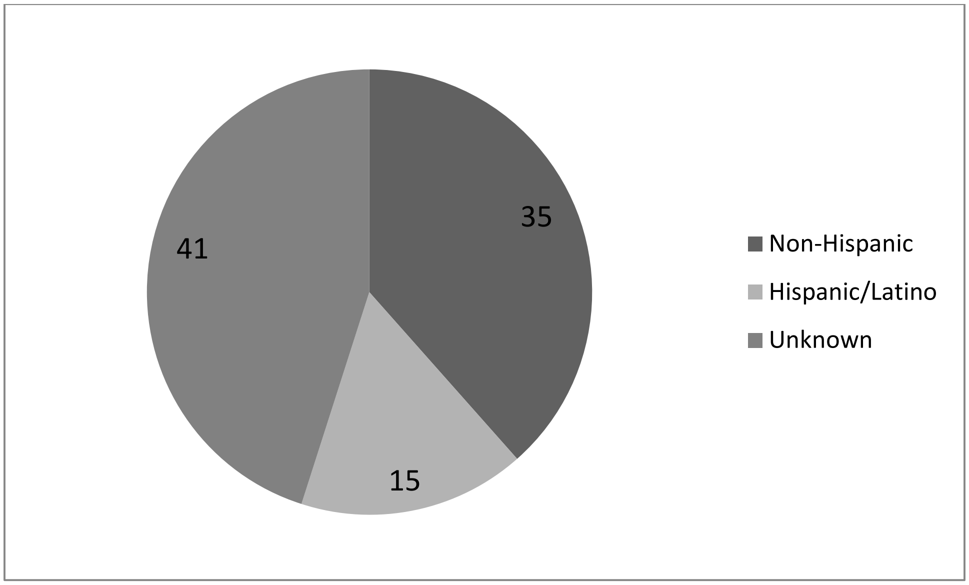

Figure 3. Number of cases of autism in Lane County, Oregon, by ethnicity.

Water Source. For the number of participants who had city and private water, a chi square goodness of fit test was conducted to assess if significant differences existed in the number of city vs. private water sources. The majority of cases fell into the category of city water (n = 75, 82%). The chi square goodness of fit test was used to assess if a significant difference exists between the expected 50:50 ratio and the observed ratio. Results of the test were significant, $\chi^2(1) = 40.00$, $p < .001$. This suggests that the ratio between city and private water was significantly different from an equal 50:50 split. Significantly more participants had city water compared to private water. Table 3 presents frequencies and percentages within the study population for water source.

Table 3

Frequencies and Percentages for Water Source

Water Source	***n***	**%**
City	75	82
Private	15	17

Birth Year. The most frequent responses for birth year were 2008, approximately age 6 (12, 13.2%), and years 2003 and 2006, approximately ages 4 and 2, respectively (10, 11%). The frequency for birth years representing typical pre-school ages, 2010–2014, was 3%. Birth years representing typical elementary school years, kindergarten through fifth grade, or 2004–2009, accounted for 42% of the cases. Birth years for middle school aged cases, 2001–2003, accounted for 27% of the cases, whereas high school aged cases with birth years of 1996–2000 accounted for 28%. There were no cases for ages 0–2, which may indicate that diagnoses were not made as often at such a young age. This was consistent with national statistics indicating that diagnosis is not made on average until age four or older (CDC, 2015). Table 4 displays the frequency of cases by birth year.

Table 4

Number of Cases of Autism in Lane County, Oregon, by Birth Year

Birth Year	**# of Cases**
1996	5
1997	4
1998	5
1999	4
2000	5
2001	7
2002	7
2003	10
2004	3
2005	6
2006	10
2007	4
2008	12
2009	3
2010	2
2011	1

Comorbidities. Communication dysfunction was the most-common comorbidity, manifested in 74% of the participants (n = 67). Cerebral palsy was the least-common comorbidity, with only 2% manifestation in the participants (n = 2). Close to half of the participants had behavioral dysfunction (n = 41, 45%). A total of 12 participants (13%) were identified as having mental illness, which was not consistent with the national prevalence of approximately 77% of the ASD population (Mukkaddes et al., 2010). This percentage was consistent with the national non-ASD population, which presents with a prevalence of 13% to 17% (Rosenquist et al., 2011). A classification error may have occurred if the participant was classified as having behavioral dysfunction instead of mental illness. However, adding 45% classified with a behavioral dysfunction to the 13% with mental illness is still below the national average of 77% for the ASD population. A total of 18 participants (20%) had an intellectual disability (ID) compared to the national average of 44% for the ASD population (CDC, 2015). Only 10 participants (11%) did not have a comorbidity. Table 5 presents frequencies and percentages for comorbidity within the study population.

Table 5

Frequencies and Percentages for Comorbidities

Possible Dependent Variables		
Comorbidities*	***n***	**%**
Communication dysfunction	67	74
Behavioral dysfunction	41	45
Gross motor dysfunction	34	37
Fine motor dysfunction	26	29
Intellectual disability	18	20
Emotional problems	14	15
Other	13	14
Mental illness	12	13
Visual dysfunction	11	12
None	10	11
Seizures/epilepsy	9	10
Hearing dysfunction	6	6
Cerebral palsy	2	2

Note. Participants could fall into more than one category.

Intellectual disability. Of note, only 20% had an intellectual disability (ID), compared to the national average of 44% of all ASD cases (CDC, 2015). There were 23 cases representing the typical high school years, with nine cases with ID accounting for 39%. There were 24 cases representing the typical middle school years, with four cases with ID accounting for 17%. There were 38 cases representing the typical elementary school years, with only three cases with ID accounting for approximately 8%. Overall, the percentage of participants with a comorbidity of an ID decreased 31% from high school aged to elementary aged participants. This supports the overall national trend of this comorbidity decreasing, but the overall Lane County ASD rate of ID of 20% prevalence is not consistent with the national average of 44%.

Zip code and cases. The most frequent response for zip code was 97478 (n = 26, 28.5%), found within Springfield, Oregon. Table 6 presents frequencies and percentages within the study population by zip code.

Table 6

Frequencies and Percentages by Zip Code

Zip Code	***n***	**%**
97478	26	29
97402	14	15
97404	12	13
97477	10	11
97401	5	5
97405	5	5
97487	5	5
97424	3	3
97439	2	2
97448	1	1
97453	1	1
97454	1	1
97408	1	1
97426	1	1
97413	1	1
97489	1	1
97490	1	1
97492	1	1

Note. Due to rounding error, percentages may not add up to 100.

Birth year and case by water source. City-sourced water had been used in the three highest birth year responses: 2008, 2003, and 2006 (n=32). Likewise, city-sourced water had been used in 87.1% of the cases. Table 7 presents the number of cases of autism in Lane County by birth year and water source.

Table 7

Number of Cases of Autism in Lane County by Birth Year and Water Source

Birth Year	# of Cases	City	Private
1996	5	4	1
1997	4	2	2
1998	5	5	0
1999	4	3	1
2000	5	4	1
2001	7	6	1
2002	7	7	0
2003	10	6	4
2004	3	3	0
2005	6	5	1
2006	10	9	1
2007	4	4	0
2008	12	10	2
2009	3	2	1
2010	2	2	0
2011	1	1	0
No Year	3	3	0

Zip code and water source. The number of ASD cases by water source was examined within each zip code using statistical geographical software. Zip code 97478, located in Springfield, represented the most cases, above 18.8, and 97477 fell within the 6.3–12.5 ranges set by Epi Info software. In Eugene, zip codes with the highest count were 97404 and 97402 and fell within the 6.3–12.5 range (see figure 4). These zip codes are in urban areas using primarily city-sourced water. It is unclear if families with children with ASD move to Springfield for the lower cost of living, thereby making it more affordable if a parent is unable to work outside the home due to caring for a child with a disability. If this is true it would present a confounder to this study, but may explain why the prevalence is higher in Springfield than in Eugene. As part of the analysis, Figure 4 illustrates that 97402 and 97404 in Eugene and 97477 and 97478 in Springfield had the highest number of cases for cases consuming city-sourced water and also by population for zip codes with populations over 1000. Of note, these zip codes are adjoining within each respective city. Appendix C displays additional maps of ASD cases in Lane County to provide geographical representation of zip code proximity based on cases, water source and population.

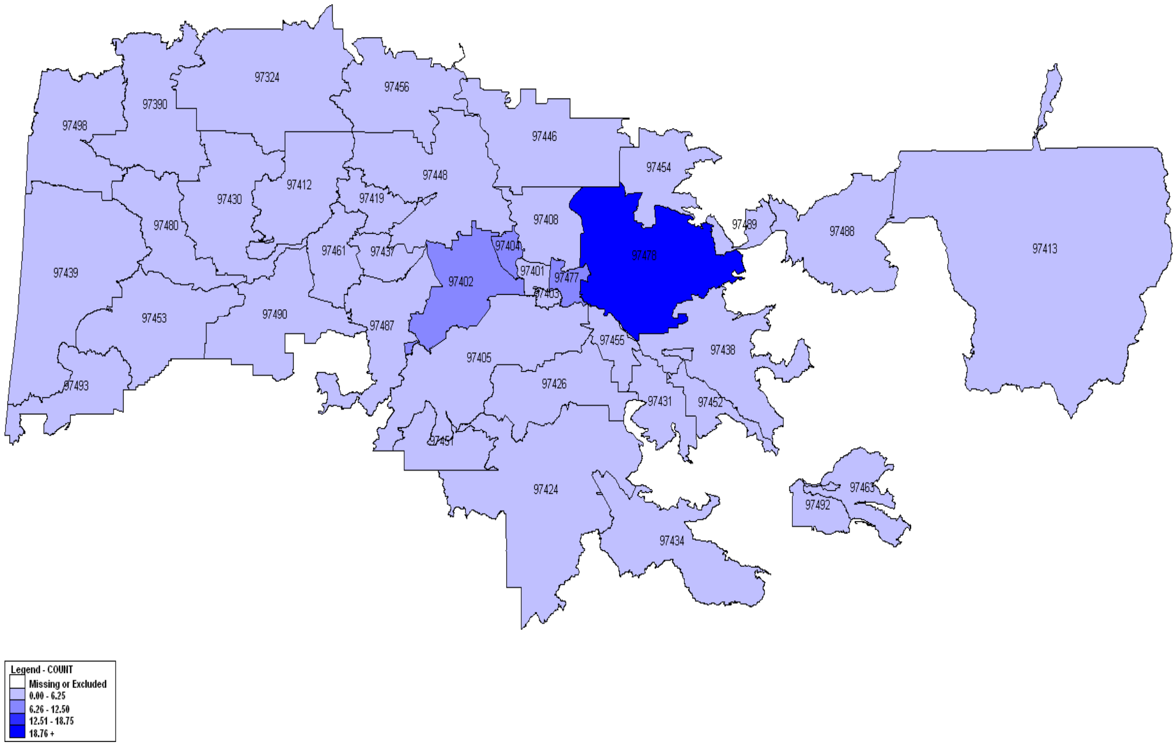

Figure 4. City-sourced water ASD cases by zip code in Lane County

Legend

Missing or Excluded
0.01– 61.00
61.00 – 122.00
122.01 – 184.00
184.01 – 245.00
245.01

Inferential Testing Findings

Chi-square Analysis

Gender and comorbidity. Chi-square tests of independence were performed to examine the relation between gender and rates of comorbidity and found that males had significantly higher comorbidity rates (21%) of emotional problems than females (0%),

X^2 (1, n = 91) = 4.43, $p < .05$, while females had higher rates (17%) of hearing comorbidity than males (4%), X^2 (1, n = 91) = 3.94, $p < .05$. Males were more likely to be diagnosed with emotional problems in addition to autism, and females were more likely to be diagnosed with hearing dysfunction. Table 8 shows the comparison of ASD cases by comorbidity and gender.

Table 8

Comparison of Individual Comorbidity Rates by Gender

	Male		Female			
Comorbidity	# With	# Without	# With	# Without	χ^2	*p*
Communication	56	17	12	6	0.77	0.38
Behavioral	35	38	7	11	0.13	0.72
Gross Motor	28	45	6	12	0.16	0.69
Fine Motor	23	50	3	15	1.56	0.21
Emotional	15	58	0	18	4.43	< .05
Intellectual Disability	12	61	6	12	2.60	0.11
Mental Illness	10	63	2	16	0.08	0.77
Seizure	8	65	1	17	0.47	0.49
Vision	8	65	3	15	0.44	0.51
Hearing	3	70	3	15	3.94	< .05
Cerebral Palsy	2	71	0	18	0.50	0.48
Other	12	61	2	16	0.31	0.57

Water source and comorbidities. An analysis was completed to compare the number of comorbidities by water source. The number of comorbidities ranged from zero to six, with an average of 2.7. Figure 5 depicts the average number of comorbidities by water source. Because the data were not normally distributed, the non-parametric Mann Whitney U test was conducted instead of the independent sample *t*-test. The Mann Whitney U test ranks the data for comorbidities and compares the ranks for both groups. The results of the Mann Whitney U test were not significant, $z = -1.54$, $p = .123$. This suggests that the number of comorbidities was not significantly different by the source of water. Table 9 presents the results of the Mann Whitney U test. The number of comorbidities by water source was not significant at the $p < .05$ level (see Table 5). The findings do not support water source as an association with any of the individual comorbidities studied (Table 10). Thus, the null hypothesis that there is no association between city-provided and private-sourced water and the presence of ASD diagnosis among persons aged 0-17 years in Lane County cannot be rejected.

Table 9

Mann Whitney U Test for Number of Comorbidities by Water Source

	Mean Rank			
Variable	City	Private	*z*	*p*
Number of comorbidities	47.37	36.13	-1.54	.123

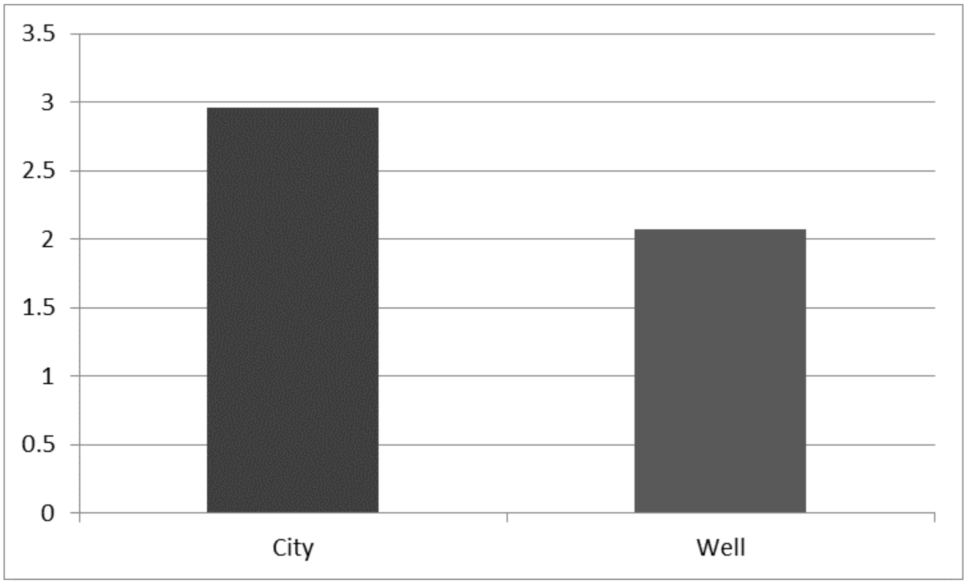

Figure 5. Average number of comorbidities per case by water source.

Table 10

Comparison of Individual Comorbidity Rates by Water Source

	City		Private			
Comorbidity	# With	# Without	# With	# Without	χ^2	*p*
Communication	58	17	9	6	1.97	0.16
Behavioral	37	38	4	11	2.59	0.11
Gross Motor	30	45	4	11	0.95	0.33
Fine Motor	22	53	4	11	0.04	0.84
Intellectual Disability	14	61	4	11	0.50	0.48
Emotional	13	62	1	14	1.08	0.30
Mental Illness	11	64	1	14	0.69	0.41
Seizure	9	66	0	15	2.00	0.16
Vision	9	66	2	13	0.02	0.89
Hearing	6	69	0	15	1.29	0.26
Cerebral Palsy	2	73	0	15	0.41	0.52
Other	10	65	3	12	0.45	0.50

Water source by zip code and population. The most frequent response for zip code was 97478 (n = 26, 28.6%) representing Springfield, Oregon, with a population of 37,011. The next highest response in Springfield was zip code 97477 (n = 10, 11%). Eugene, Oregon, is the largest city in Lane County with a population of 179,474. The two most frequent responses for Eugene were in zip codes, 97402 (n = 14, 15%) and 97404 (n = 12, 13%). Comparing the two highest response zip codes in Springfield and Eugene, Springfield represents approximately 40% of the cases, whereas Eugene represents only

28% of the cases. Springfield city water is well-sourced and supplemented by surface-sourced water from the Middle Fork Willamette River provided by the Springfield Utility Board (SUB, 2015). Eugene city water is surface-sourced with water from the McKenzie River provided by the Eugene Water & Electric Board (EWEB, n.d.).

The City of Eugene zip codes include 97401, 97402, 97403, 97404, 97405, 97408, and 97440, with a total city population of 179,474. These zip codes account for 36 of the ASD cases and represent .02% of the general population and 40% of the accepted ASD cases in Lane County. City-sourced water was used 93.2% of the time. The City of Springfield zip codes include 97478, 97475, and 97477, for a total population of 73,885. These zip codes account for 36 of the ASD cases and represent .05% of the general population and 40% of the accepted ASD cases in Lane County. City-sourced water was used 99.2% of the time. The City of Springfield has more than double the cases of Eugene with high city-provided water usage. A higher proportion of ASD cases was found in Springfield, Oregon, compared to other cities in Lane County. Eugene and Springfield combined account for 80% of the cases.

Table 11 presents a cross-tabulation between zip code and water source by population. For Springfield cases using city-sourced water, zip code 97478, with a population of 37,011, had an incidence rate of 6.8%. Zip code 97477, with a population of 36,874, had an incidence rate of 2.7%. These percentages are compared to the national average of 2%. Of note, these zip codes were adjoined. For Eugene cases using city-sourced water, zip code 97404, with a population of 32,255, had an incidence rate of 3.7% compared to a national average of 2%. Appendix C contains maps representing incidence based on # of city-provided water cases, # of private-sourced water cases, and # of ASD cases (# of cases/population)*100000.

Table 11

Cross-Tabulation Between Zip Code and Water Source

		City		Private	
Zip Code	Population	*n*	% of population	*n*	% of population
97478	37011	25	0.068	1	0.003
97402	50342	12	0.024	1	0.002
97404	32255	12	0.037	0	0.000
97477	36874	10	0.027	0	0.000
97401	40521	5	0.012	0	0.000
97405	44645	5	0.011	0	0.000
97424	17594	2	0.011	1	0.006
97408	11711	1	0.009	0	0.000
97426	9716	1	0.010	0	0.000
97439	14343	1	0.007	1	0.007
97448	12244	1	0.008	0	0.000
97413	915	0	0.000	1	0.109
97453	897	0	0.000	1	0.111
97454	1337	0	0.000	1	0.075
97487	8449	0	0.000	5	0.059
97489	868	0	0.000	1	0.115
97490	326	0	0.000	1	0.307
97492	597	0	0.000	1	0.168

Water source by zip code and number of households. A chi-square analysis was completed for the cases of ASD across households by water source and found no significant difference: χ^2 (1, N = 164652) = 0.24, *p* = 0.62.

Associational Hypothesis Testing Findings

A chi-square test was used to examine comorbidities and water source. No significant difference was found and the null hypothesis failed to be rejected. Equation: $CoM_i = a_0 + a_1 Water_i + e_i$

Epi Info version 7 was used to provide a visual representation of the cases by zip code and water source and may be more suggestive of trends and clusters. Geospatial examination revealed several clusters in urban environments. This leads to more questions with which to examine the differences between these zip codes, such as socio-economic status (SES), industry, access to diagnostic professionals, and proximity to landfill sites and agricultural areas. The results of this study's research, as pertains to the research questions posed, are outlined below.

Research question 1: Hypothesis $H_0 1$ stated that no significant association existed between city-provided and private-sourced water supply and the presence of an ASD diagnosis among persons aged 0–17 years in Lane County, Oregon, receiving services through Lane County Developmental Disabilities Services.

A chi-square test was used to examine categorical data between water source and ASD cases. City-sourced water accounted for 83.3% of the cases, compared to private-sourced water. However, this was not statistically significant at the *p* = .05 level when compared to the total number of households using city-sourced water. The null hypothesis failed to be rejected.

Research Question 2: Hypothesis H_02 stated that no clusters exist within a zip code or surrounding zip codes based upon population drinking water source. A chi-square test was used to examine zip codes and water source. Zip codes 97489 and 97478 had the highest incidence of using city-sourced water, and 97490 had the highest incidence of private-sourced water based on population. No significant relationship appeared. (See Figures C4 and C5). Of note, the national ASD prevalence is approximately 2% of the population. Interestingly, zip codes with populations above 5,000 exceeding the national average were Eugene zip codes 97402 (2.4%) and 97404 (3.7%), and Springfield zip codes 97477 (2.7%) and 97478 (6.8%). Zip code 97478 is more than three times the national average and adjoins with zip code 97477.

The autism cases were characterized and compared to national averages. The male to female ratio of cases (n = 73, 80%) correlated with the national average of a five to one ratio. Asian (2%) and Black (1%) cases were consistent with the national average. The data on ethnicity had 41 missing responses, or listed as unknown, which may be invalid. Three out of 17 birth years (2003, 2006, and 2008) accounted for 35.2% of the cases (n = 32). Overall, most children receiving services in 2014 were middle and high school ages.

The highest response for comorbidity was communication dysfunction and accounted for 77% of the cases (n = 67), with 11% having no comorbidity (n = 10). Males were more likely to be diagnosed with emotional problems and females were more likely to be diagnosed with hearing dysfunction. Cases with an ID comorbidity comprised

20%, compared to the national average of 44% (CDC, 2015). The number of high school aged cases with ID was 31% higher than elementary school aged cases with ID at 8% and significantly below the national average. Overall, the decrease in ID as a comorbidity of ASD is consistent with national trends; however, overall Lane County incident of ID/ASD comorbidity is less than half of the national average, and the elementary school aged participants demonstrated 8% ID comorbidity compared to 44% nationally. It is unclear if early intervention plays a role in the child's ability to learn, resulting in improved IQ scores.

Implications and Limitations

There are several possible explanations for these results. First, families may move to the city to have better access to services for their children. Rural areas may not have funding to provide specialized programs within the school, adaptive recreational opportunities, or as many natural supports. Second, families may move to Springfield to access a lower cost of living, which may benefit families with one income, or benefit parents who may be unemployed or underemployed due to an ASD condition themselves, considering the heritability of the condition. Third, an environmental exposure due to spills, leaks and agriculture may have existed around the time of higher participant birth years (2003, 2006, and 2008).

Known leaking underground storage tanks (LUSTs) and environmental spills around the time of high birth year cases were investigated. Although no environmental spill increases were noted in or between these years for any of the zip codes, there were some differences in the occurrences of LUSTs. In zip code 97402, the highest incidences of LUSTs were in 2003 (n = 10) and 2006 (n = 11), compared to an average of < 7 for the remaining years from 2001 to 2009. In zip code 97477, the highest incidences of LUSTs were in 2003 (n = 5), 2006 (n = 6), and 2007 (n = 7) compared to an average of < 2 for the remaining years from 2001 to 2009. In zip code 97404, the highest incidences of LUSTs were in 2003 (n = 6) and 2006 (n=6), compared to an average of < 2 for the remaining years from 2001 to 2009. No differences were noted for zip code 97402. Zip codes 97477 and 97404 do not share the same water source but both are city-provided water sources. However, it should be noted that the leaks may have occurred long before they were found, and therefore no association can be drawn.

In Springfield, Oregon, a saw mill used pentachlorophenol (PCP), a known endocrine disrupting compound (EDC) (Sakakibara et al., 2010), from 1948 to 1987 as a wood preservative (EWEB, 2009). As expected from groundwater modeling, elevated levels of PCP reached the wells used to supply drinking water to the City of Springfield in 2008. In 2009, levels had increased in four of the seven wells, requiring ongoing filtration and monitoring. There is one landfill for Springfield and Eugene, located in zip code 97403. It is positioned between the two cities and is less than one mile from the McKenzie River, the water source for the City of Eugene. The landfill adjoins to Springfield's zip code 97477 but not 97478, which was the highest incidence zip code.

Agriculturally related exposures due to farming and livestock were explored using the U.S. Census of Agriculture (2012). Lane County uses 1.3% (219,625 acres) of the total 16,301,578 acres of land used for agriculture in the state of Oregon. Cropland in Lane County accounts for 2.1% (100,025 acres) of the 4,690,420 acres in the state of

Oregon (U. S. Census of Agriculture, 2012). Irrigated land in Lane County accounts for 1.9% (19,311 acres) of the irrigated 1,628,735 acres in the state of Oregon (U. S. Census of Agriculture, 2012). Land used in Lane County for raising livestock and poultry accounts for 1.6% (21,363 acres) of the 1,297,945 in the state of Oregon (U. S. Census of Agriculture, 2012). Compared to national agricultural use of land, the state of Oregon accounts for 1.7% (914,527,667 acres) of the total acres used in the United States (U.S. Census of Agriculture, 2014). Cropland for the state of Oregon represents 1.2% (4,690,420 acres) of the total 389,690,414 acres used in the United States (U.S. Census of Agriculture, 2014). Irrigated land for the state of Oregon represents 2.9% (1,628,735 acres) of the total 55,822,231 acres used in the United States for irrigation (U.S. Census of Agriculture, 2014).

Oregon is not included as one of the 11 sites monitored by the Autism and Developmental Disabilities Monitoring (ADDM) network sites (CDC, 2015); however, the U.S. Department of Education reported the state of Oregon ASD prevalence range to be from 1.0% to 1.4%, one of four states with the highest prevalence for educating children (Smith, 2011).

Data and Conceptual Framework Limitations

The Integrative Model of Environmental Health (IMEH) encompasses overlapping physiological, vulnerability, epistemological, and health protection domains (Dixon & Dixon, 2002). Within the physiological domain, at the initial review of the exposure process, the data were insufficient to explore other possible variables pertaining to pre- and post-natal exposures and bioaccumulation effects, such as water transport piping, proximity to landfills, phthalate exposures within the home, and family history of exposures suspected of an association with ASD. Dixon and Dixon (2002) asserted that the health protection domain addresses efficacy and actions. Because the secondary data in this study were limited, ensuring accurate exposure information at intake may deepen exploration and improve policy regarding prevention and decreasing exposures.

Interpretation

Although the null hypotheses failed to be rejected, the data revealed some unexpected results. Cases were higher for city residents using ground-sourced water in two zip codes, compared to surface-sourced water. LUSTS and spills were higher during high birth case years in one zip code each for Eugene and Springfield. There was a ground-sourced contamination of EDCs in 2009, a high case birth year. This contaminated water source supplies water to zip codes 97477 and 97478, the zip codes containing the highest number of cases. However, results did not reach statistical significance.

Mental illness was identified in only 13% of the cases, instead of 77% of the ASD population as suggested by previous research (Mukkaddes et al., 2010). However, participants may not have been diagnosed yet, or they were classified with a behavioral or emotional disorder instead. Only 20% had an intellectual disability compared to the national average of 44% (CDC, 2015), indicating increased potential for post-secondary education, employment, and independent living opportunities. Likewise, this low incidence of ID could be a result of poor diagnosis upon intake.

Summary

In summary, high frequency ASD cases in Lane County, Oregon, were distributed as follows: 82% White, 80% with normal to above normal IQ, 80% male, 74% with communication dysfunction, and 55% living in Springfield zip codes 97478 and 97477 or Eugene zip code 97402. There was known EDC water contamination for zip codes 97478 and 97477. The comorbidity of mental illness was diagnosed in only 13% of the participants compared to 77% nationally, and more closely reflects the national non-ASD population frequencies of 13% to 17% (Rosenquist et al., 2011). One possible explanation is that participants may have been misclassified as having emotional or behavioral disorders instead of mental illness if a definitive diagnosis was not yet made at the time of intake.

Chapter 5: Summary, Conclusions, Limitations, and Implications

Overview

Utilizing patient-level data from the State of Oregon, Department of Human Services, Lane County Developmental Disabilities Services, this study explored cases of autism spectrum disorder (ASD) among 276 children, aged 0–17 years, residing in Lane County, Oregon, who received services in April 2014. The purpose of this study was to determine if water source is associated with ASD cases in Lane County, Oregon. This study compared water sources in relation to incidents of autism, generally explored incidents of comorbidities, and examined ASD incident rate by geographical location. After excluding data that was incomplete and met exclusion criteria described in Chapter 3, the final study data set consisted of 91 cases. Eighty percent were boys (n = 73), 70% were White (n = 64), and 17% were Hispanic (n = 15). Eighty-two percent (n = 75) utilized a city water source and 17% (n = 15) had a private water source. Communication dysfunction was the most-common comorbidity, manifested in 74% of the participants (*n* = 67). Forty-two percent were kindergarten age through fifth grade, 27% were middle school aged cases, and 28% were high school aged. The most frequent response by zip code was in 97478 (n = 26, 28.5%), found within Springfield, Oregon. ASD incident rates related to city-sourced and private-sourced water were examined using geospatial mapping analysis to identify clusters of ASD cases. Analysis of sociodemographic variables allowed for identification of trends. This chapter summarizes the conclusions drawn from this study and outlines the limitations as well as the implications of the findings to research, policy, and social justice.

Summary

ASD is of great public health concern because prevalence is rapidly increasing and there is no known cause or cure. Prevalence is expected to continue increasing worldwide, yet the etiology of autism and the methods for its prevention remain undefined. Given that there is significant research indicating the association of water with other health issues, researching water sources as an environmental differentiator for ASD is of great value. However, there was only one relevant study found in the review of the literature regarding this subject. This research aimed to extend the current data on environmental links to ASD etiology, particularly in regards to water source.

The conceptual framework of the Integrative Model of Environmental Health (IMEH) (Dixon & Dixon, 2002) was used to establish a narrative and conduct this research. This model incorporates overlapping physiological, vulnerability, epistemological, and health protection domains. These domains provide a framework for determining which data, including relevant variables and factors, should be collected as well as a narrative for understanding and interpreting these data. The physiological domain provides a framework for identifying, understanding, and interpreting the physical impact of an exposure on a particular population; in this case, exposure to a specific water source and the development of ASD. For this study multiple geographical areas within Lane County, Oregon were selected for comparison. Data that met exclusion criteria, such as potential water sources outside of Lane County, foster children, adopted children, and children who were born outside of Lane County were eliminated from the data set. Prevalence of ASD was compared to water source exposure (city-sourced, private-sourced, surface-sourced, and ground-sourced).

The vulnerability domain addresses the susceptibility factors—such as sensitivity, genetics, and life and disease status of the individual—and characteristics of ASD cases as well as the proximity to sources of pollutants that may play a role in the development of ASD. This domain guided the choices made regarding water source and geographical area investigation. Data was obtained from local municipalities regarding city-sourced and private-sourced water, agricultural use of land as well as examining known environmental LUSTs and spills in Lane County, Oregon. The epistemological domain addresses current knowledge and a population's understanding an issue. The etiology of ASD is unknown and the general population's understanding of it reflects this lack of knowledge. In order to prepare and educate those with vulnerabilities, there must be more data regarding etiology. Efficacy and actions fall within the health protection domain and could not be addressed as an association was not established in this study.

Water source was not found to be a significant differentiating factor in the presence of ASD diagnoses in Lane County. Due to the limitations and cross-sectional design of this investigation, there may be causal links between ASD and water source that could not be uncovered in the present research. However, this study may provide a means to explore the IMEH epistemological domain to better understand the target population's knowledge of and belief in environmental threats and ultimately determine the appropriate health protection measures to prevent or minimize exposures in the development of ASD.

The summary of findings for the two research questions are listed below.

1: There was no relationship between water source and incidence of either ASD or comorbidities.

2: There was no significant relationships or clusters of ASD populations by zip code and water source.

It was also noted the incident rates matched those of the general ASD population, except rates of (a) Intellectual Disability (ID) — much lower than the national average, and (b) mental illness —much lower than the national average for ASD; more in line with the national average for the non-ASD population.

Implication for Future Research

Although water type and source were not found to be associated with ASD cases, some of the findings do not mirror the national norms (e.g., prevalence with ID and mental health comorbidities) and lack explanation. Further in-depth research may be helpful in explaining the differences found in the ASD population and the differences between zip codes. Data on the spatial distribution of ASD, particularly the higher incidence in urban areas, could lead to closer examination of urban environmental insults and thereby allow for rapid response to risk areas. Results provided initial data that could serve as a foundation for further evaluation, possibly allowing public health agencies to respond proactively to areas of increased risk through developed surveillance systems in a real-time manner. Although this study had limited power, given that it was snapshot of a small geographical area, further research may improve understanding of potential exposures leading to the development of autism. To enrich the data, for example, an environmental exposure questionnaire may prove beneficial to gaining a better understanding of how exposures play a role in ASD development. A longitudinal study in the areas this research studied would further these data, and together with exposure information, might better pinpoint environmental causes.

Employment rates and quality of life of ASD affected families are significantly lower than in the non-ASD population (Ganz, 2007). Research shows that having a child with autism negatively impacts the earning capacity of the parents due to increased caregiving complexities and responsibilities (Ganz, 2007). Two zip codes in the low cost area of Springfield account for a large number of ASD cases. Therefore, it may be useful for future studies to examine the role of gentrification for families with children with autism. Gentrification may drive these families into low cost areas and create pockets of families with significant financial disparities. As the ASD population increases and populates more disadvantaged areas, health disparities may result between high and low income areas. Further research identifying environmental exposures and possible gentrification may be beneficial.

Limitations

There were four major limitations to this study. First, there is risk of misclassification of exposure, as the child may have changed residence since exposure to the water source at birth and early development. Drinking water currently consumed by the child may not have been the same as that consumed in utero or during childhood, and data was only collected for a single point in time; only circumstantial associations can be made about the role of water consumption. Additionally, data was not available to measure consumption of bottled water, other home water treatment systems, or type of piping used for water transport to the home.

Second, based upon sample size calculations for an alpha of .05 and a power of .80 there may be insufficient power for a cross-sectional design. Although there were initially 276 ASD cases, more than double the expected sample size needed, exclusion criteria reduced the sample to 91 viable cases, which may not be strong enough to represent the impact of water source and ASD development. Based on the sample size estimates, this study may not have sufficient power or normal distribution. Minimizing missing data would have increased the sample size.

Third, information obtained was taken from the intake interview, with parent self-reporting as the fundamental criteria for some of the variables, and in many cases parental assessment was not verified with other medical documentation. There may be a dearth of qualified medical personnel in the area in general, and in specific there may be a dearth of professionals capable of accurately diagnosing autistic spectrum disorders. Parental report of comorbidities is a particular limitation, as very few parents are qualified to make assessments of mood, intellectual, or developmental disabilities. However, there must be a certain degree of trust in the intake system of Lane County, and this basic level of diagnostic trust is the basis for the data used in this study.

Fourth, the study’s findings cannot be generalized to populations outside of Lane County, Oregon, and no inferences should be made regarding exposures to other areas or populations. Lane County DDS has definitions for ASD and comorbidity presentation that may differ significantly from those of other counties, states, and nations. The establishment of rigorous standardization of definitions across health departments would strengthen future studies in this area. It is also recommended that an in-depth environmental exposure questionnaire accompany intake forms to begin collecting data for future research, such as accompanied the National Center for Geospatial Medicine study discussed earlier.

Implications for Social Change and Recommendations

Implications for positive social change include the importance of improved data collection required by social service agencies that may deepen our understanding of ASD risk factors. Additionally, this study highlighted the need for additional research to deepen our understanding of water quality and its possible role in the development of ASD. This study may facilitate changes in documentation requirements that may lead to an improved understanding of possible variables that may lead to ASD development and the need for a more in-depth and broader study of the role water may play in the development of ASD. It is recommended to improve documentation by defining each comorbidity to obtain consistency between parents' reports and those of county case workers. Data revealed that the definition of each comorbidity was not standardized and not consistently verified by a specialist. Based upon the study results and compared to national statistics, misclassification of comorbidities may have occurred as they are parent reported and a clinical diagnosis by a psychiatrist or psychologist may not have been made upon intake. Well-defined definitions may aid the parents and intake coordinators in selecting comorbidities correctly. Additionally, clear definitions could prompt the parent or case worker to obtain an assessment for potential diagnosis and early intervention. Early intervention could significantly improve lifelong outcomes.

Within the IMEH model, the vulnerability domain allows for the assessment of individual and community characteristics (Dixon & Dixon, 2002). Results of this study found 80% of the participants in this study to have average to above average IQ, compared to 50% nationally, indicating potentially increased opportunities to advance post-secondary education and skills training for employment. The ASD population tends to possess strengths in certain areas of knowledge and application (Wei, Yu, Shattluck, McCraken, & Blackorby, 2013), and further research on maximizing these specializations through alternative education paths could result in a powerful boost to humanity's overall advancement. For example, within the science, technology, engineering, and mathematics (STEM) fields, researchers found that the college ASD student population had the highest participation rate. However, within 11 different disability groups, ASD students overall had the third lowest college enrollment rate (Wei et al., 2013). These results may spur changes to primary education curricula for this population, as well as college and technical skills training for adults with ASD, thereby boosting employment and independent living options. The need for lifelong supports might decline and quality of life might be optimized.

A larger study to include additional counties and participants not receiving services is recommended. This study only examined participants in Lane County, Oregon, receiving services from Lane County Developmental Disabilities Services (DDS) and excluded participants who may have received services from other agencies, such as the school system. The study also excluded participants who did not require support outside of their family. Working with healthcare providers and private agencies to recruit participants who do not receive services through DDS or the school system will provide a better representation of the population. A more robust study would include these participants and participants from other counties and the school system, perhaps found through a call to action in the schools, or a distributed recruitment survey. Data collected at the county and state level is limited and does not address environmental exposures outside of drugs and alcohol. For example, new research led by the National Center for Geospatial Medicine is underway to explore ASD and the associations between potential environmental and social stressors that are location-specific (Progressive Tech Federal System, Inc. [PTFS], 2014). Using geospatial analysis, researchers will collect data on tens of thousands of volunteers with ASD. This large and broad study will collect data such as water sources, water quality, land use, proximity to industrial facilities, and data on the mother's exposures during preconception, pregnancy, and the early years of the child's life. Researchers hope to begin identifying patterns that lead to the development of ASD (Progressive Tech Federal System, Inc. (PTFS), 2014). Finally, the definition of drugs is not provided; therefore, it does not address herbal supplements or prescribed and illicit drugs. Additionally, because responses are only self-reported, answers may not be reliable because of a parent's fear of having their child removed from the home by protective services. Overall, this study underscored the need for policymakers to standardize comorbidity definitions for improved data quality and highlighted the value of including an environmental questionnaire and the need for further research.

Conclusion

Autism continues to increase in the United States, but increases in its prevalence cannot be explained by better diagnosis alone (Hertz-Picciotto & Delwiche, 2009). CDC estimates have risen from one child in every 150 (CDC, 2007) to one child in 50 (Blumberg, 2013), making it a significant public health problem. This dissertation examined a link between the prevalence of ASD and water source. There is no known cause for the development of ASD, and many suspect environmental factors. Therefore, it was important to examine whether water exposure is linked to the development of ASD. Although this study showed no association between city-provided or private-sourced drinking water supply and presence of an ASD diagnosis among persons aged 0–17, more in-depth research is advised to determine if drinking water plays a role in the development of ASD.

No significant association was found between water source and ASD cases in Lane County, Oregon. However, mapping of cases for visual examination revealed prevalence exceeding the national average within four zip codes. In Springfield, Oregon, one of the zip codes, 97478, had more than three times the national average and adjoins with another zip code exceeding the national average, 97477. The City of Springfield water is primarily ground-sourced from wells and supplemented by surface-sourced water from the Middle Fork Willamette River, compared to Eugene city-provided water from surfaced-sourced water from the McKenzie River. Higher incidence may suggest that additional research specific to the known endocrine disrupting compound (EDC) water contamination that occurred there in 2009 and the continued testing of the seven wells used for Springfield's water sources may be productive. Further research is warranted to gain a better understanding of the different variables between zip codes that may account for the increase in ASD cases. Urban environments may contribute to the cause, or at least the diagnosis, of autistic spectrum disorders and may have social implications in the geographical area study as well as nationally. Additionally, this research contributed to the currently small amount of data on environmental causes of ASD through drinking water exposure.

Although much is known about ASD, more information is vitally needed to determine risk factors and possible causes (CDC, 2015). Autism continues to increase among American children. Between 2007 and 2009, the CDC reported an average increase from one in 150 children to one in 110 children (CDC, 2015). While improved awareness and identification accounted for some of this increase, the CDC could not rule out a true increase in risk, particularly among boys, who are now 4.5 times more likely than girls to be diagnosed with an autism spectrum disorder (ASD). New studies will give us a better idea of which of the many possible risk factors including, genes, health conditions, experiences of the mother during pregnancy, health and development, and environmental factors are related to the development of ASD.

Additionally, the study framework provides no explanation for the much higher percentage of ASD participants with normal to above normal IQ than the national average. Based upon the overall known evidence, it can be speculated that this was because cases were identified early allowing for individualized education and additional supports within the school and home. These advancements may result in improved quality of life for individuals with ASD worldwide. Moreover, these findings may spur meaningful research to further enhance education and human service policy.

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Appendix A

Definition of Terms and Symbols

Descriptive Statistics

Researchers use descriptive statistics to describe and explore the main characteristics of the variables.

M (mean). The average value of a scale-level variable.

SD (standard deviation). The spread of the data around the mean of a scale-level variable.

n: The number of times a nominal or ordinal category is counted.

% (percentage). The percentage of the frequency or count of a nominal or ordinal category.

Comorbidity Definitions

The Lane County Developmental Services Department uses the following categories to define observed or previously diagnosed conditions upon intake and reported by the intake worker or the parent. A health care provider later verifies these conditions. The following are broad definitions health care providers may use to diagnose a person.

Behavior Dysfunction: “A disorder characterized by displayed behaviors over a long period of time which significantly deviate from socially acceptable norms for a person’s age and situation (McGraw-Hill Concise Dictionary of Modern Medicine, 2002, para.1).

Cerebral Palsy: “Cerebral Palsy is a group of disorders that affect a person’s ability to move and maintain balance and posture” (CDC, 2015a).

Communication Dysfunction: "Impairment in the ability to receive, send, process, and comprehend concepts or verbal, nonverbal and graphic symbol systems. A communication disorder may be evident in the processes of hearing, language, and/or speech. A communication disorder may range in severity from mild to profound. It may be developmental or acquired. Individuals may demonstrate one or any combination of communication disorders. A communication disorder may result in a primary disability or it may be secondary to other disabilities" (American Speech-Language-Hearing Association, 1993, para. 2).

Emotional Problems: “Emotional disability psychiatry behavior, emotional, and/or social impairment exhibited by a child or adolescent that consequently disrupts the child's or adolescent's academic and/or developmental progress, family, and/or interpersonal relationships” (McGraw-Hill Concise Dictionary of Modern Medicine, 2002).

Fine Motor Dysfunction: A dysfunction of “coordination of muscles, bones, and nerves to produce small, precise movements” (Kimmel & Ratliff-Schaub, 2015, para. 1).

Gross Motor Dysfunction: “The acquisition and execution of coordinated motor skills is substantially below that expected given the individual’s chronological age and opportunity for skill learning and use” (American Psychiatric Association, 2013c).

Hearing Dysfunction: “Hearing loss can be congenital or acquired, progressive or sudden, temporary or permanent, unilateral or bilateral, and mild or profound” (O'Neil, 2011, p. 1378).

Mental Illness: “A mental disorder is a syndrome characterized by clinically significant disturbance in an individual’s cognition, emotion regulation, or behavior that reflects a dysfunction in the psychological, biological, or developmental processes underlying mental functioning” (American Psychiatric Association, 2013c, p. 707).

Intellectual Disability: “A disorder with onset during the developmental period that includes both intellectual and adaptive functioning deficits in conceptual, social, and practical domains” (American Psychiatric Association, 2013c, p. 33).

Seizures or Epilepsy: “Consists of sudden synchronous high-frequency firing by localized groups of neurons in certain brain areas” (O'Neil, 2011, p. 1610).

Visual Dysfunction: “Distortion of vision is an inability to see clearly and correctly. This distortion may involve a poor focus due to a refractive error, lack of depth perception, double vision, glare or halos, flashes of light or floaters. It may also involve color blindness” (O'Neil, 2011, p. 1417).

Water Source Definitions

Surface-sourced water: “water that collects on the ground or in a stream, river, lake, reservoir or ocean” (CDC, para 2, 2009).

Ground-sourced water: “which is obtained by drilling wells, is water located below the ground surface in pores and spaces in the rock” (CDC, para 3, 2009).

Private-sourced water: “private, or individual, water systems are composed of private ground water residential wells, cisterns, and larger private water systems that serve more than one residence but no more than 25 people at least 60 days of the year and have no more than 15 service connections” (CDC, para 3, 2014). They are not regulated by the EPA (CDC, 2014).

Appendix B

Variables, Coding, and Exclusions

Water Source by Address	Addresses indicating City-sourced water were coded 0; Addresses indicating private-sourced well water were coded 1.
Birth Years	Birth years included 1997 through 2014.
Place of Birth	Cases born outside of the state of Oregon are excluded.
Race	Asian, Alaskan Native, Pacific Islander, African American, Native American, White, Black, Native Hawaiian, Other/Unknown.
Ethnicity	Hispanic, Not Hispanic, Unknown.
Zip codes	97324, 97390, 97401, 97402, 97403, 97404, 97405, 97408, 97409, 97412, 97413, 97419, 97424, 97426, 97427, 97430, 97431, 97434, 97437, 97438, 97439, 97440, 97446, 97448, 97451, 97452, 97453, 97454, 97455, 97456, 97458, 97461, 97463, 97477, 97478, 97480, 97482, 97487, 97488, 97489, 97490, 97492, 97493, 97498.
Pre-natal exposures	Cases were excluded if there were known pre-natal exposures to drugs.
Comorbidities	Intellectual Disability (ID) listed as Mental Retardation, cerebral palsy, Down syndrome, epilepsy, motor issues, communication, vision impaired, hearing impaired, mental or emotional behavioral, traumatic brain injury, or acquired brain

	injury.
Living Situation	Biological (B), Foster (F), and Adopted (A). Foster and adopted cases were excluded.

Appendix C

Maps of ASD Cases by Zip Code

Maps of ASD cases in Lane County to provide geographical representation of zip code proximity based on cases, water source and population. Darker colors indicate higher numbers of cases: zip code 97402 in Eugene and 97477 and 97478 in Springfield. Figure C2 and Figure C3 show the zip code maps by water source, city and private, respectively. For city water, 97402 and 97404 in Eugene and 97477 and 97478 in Springfield had the highest number of cases. For private sourced water, zip code 97487 in Springfield had the highest number of cases. Figure C4 shows ASD cases by population. Figure C5 shows city-sourced water case incidence by population. Figure C6 shows private-sourced water case incidence by population.

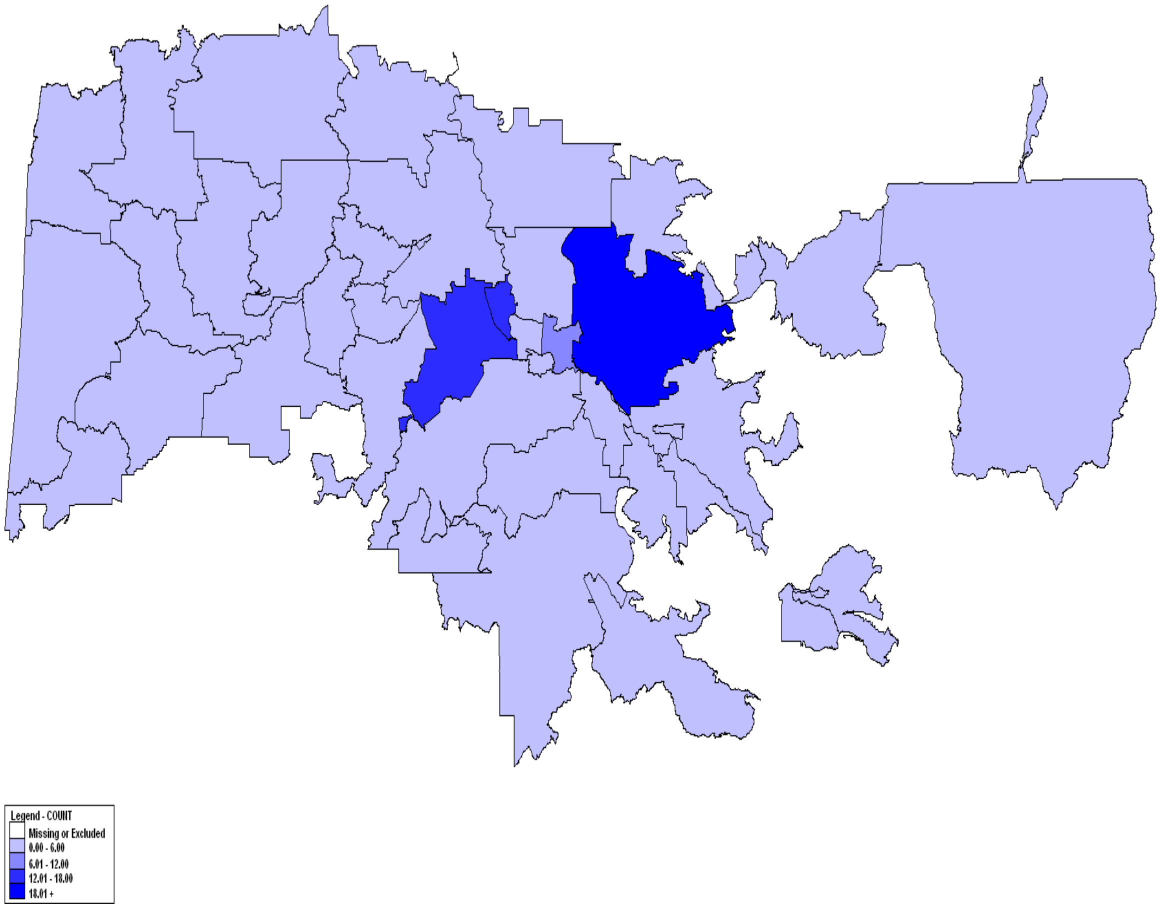

Figure C1. ASD cases by zip code in Lane County.

Legend

Missing or Excluded
0.01– 61.00
61.00 – 122.00
122.01 – 184.00
184.01 – 245.00
245.01

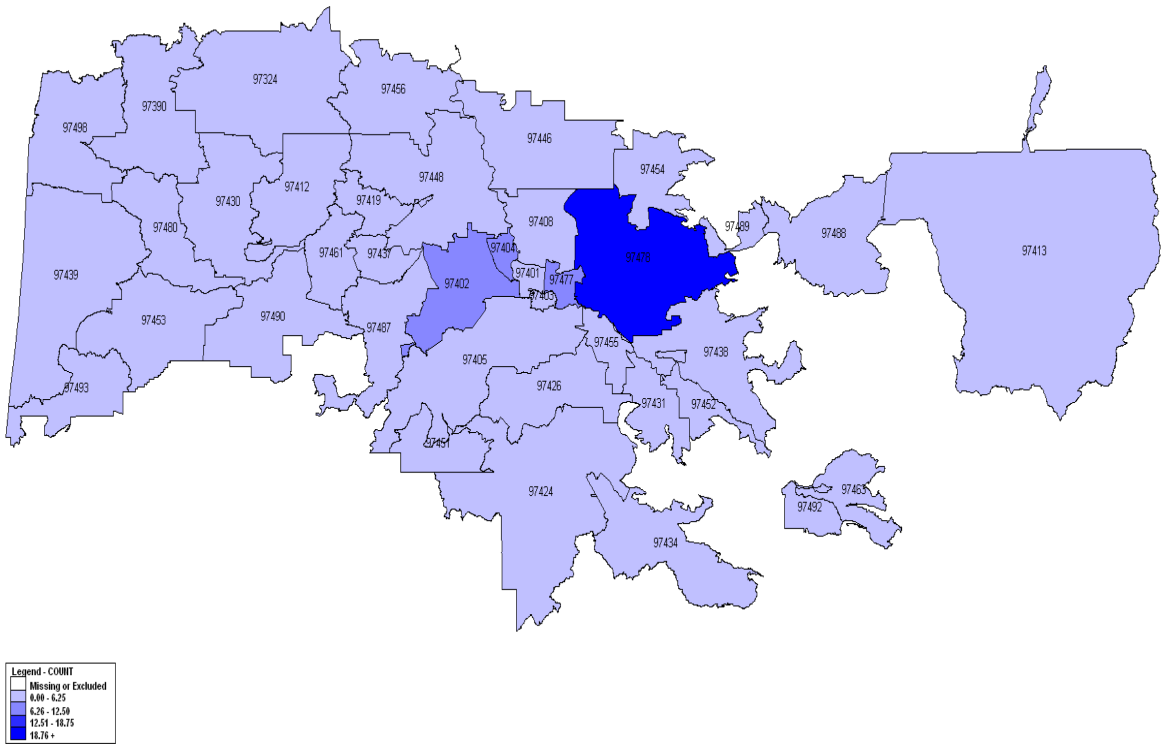

Figure C2. City-sourced water ASD cases by zip code in Lane County

Legend

Missing or Excluded
0.01– 61.00
61.00 – 122.00
122.01 – 184.00
184.01 – 245.00
245.01

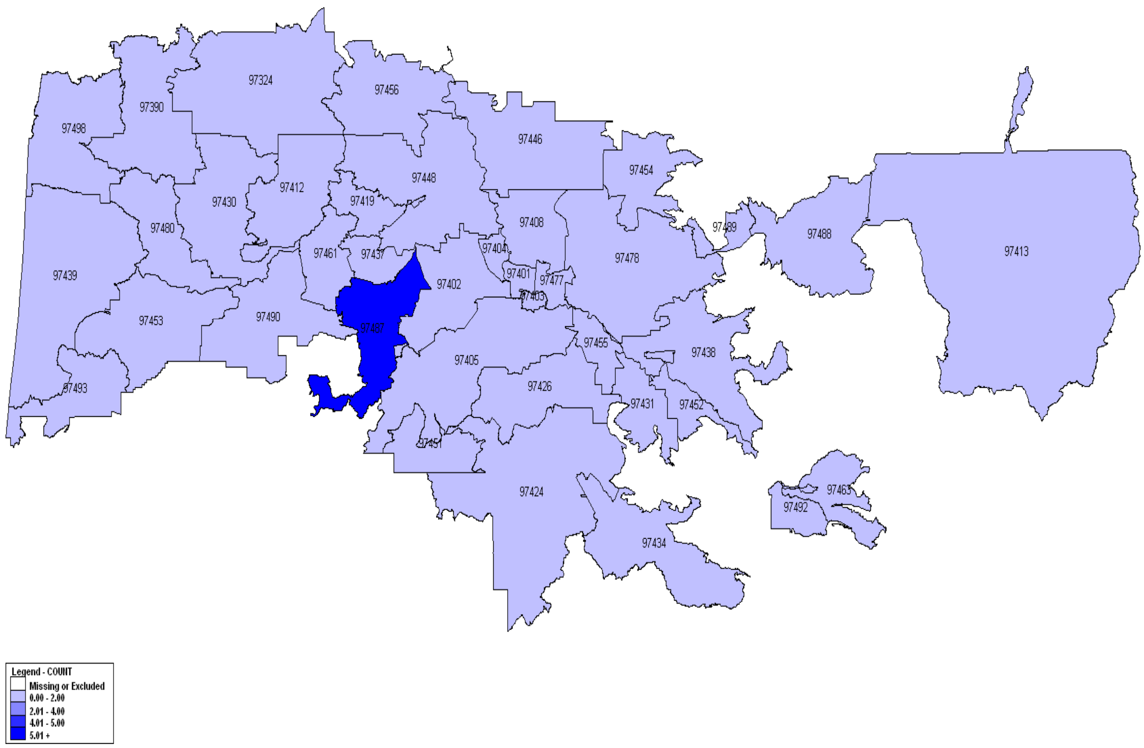

Figure C3. Private-sourced water ASD cases by zip code in Lane County

Legend

Missing or Excluded
0.01– 61.00
61.00 – 122.00
122.01 – 184.00
184.01 – 245.00
245.01

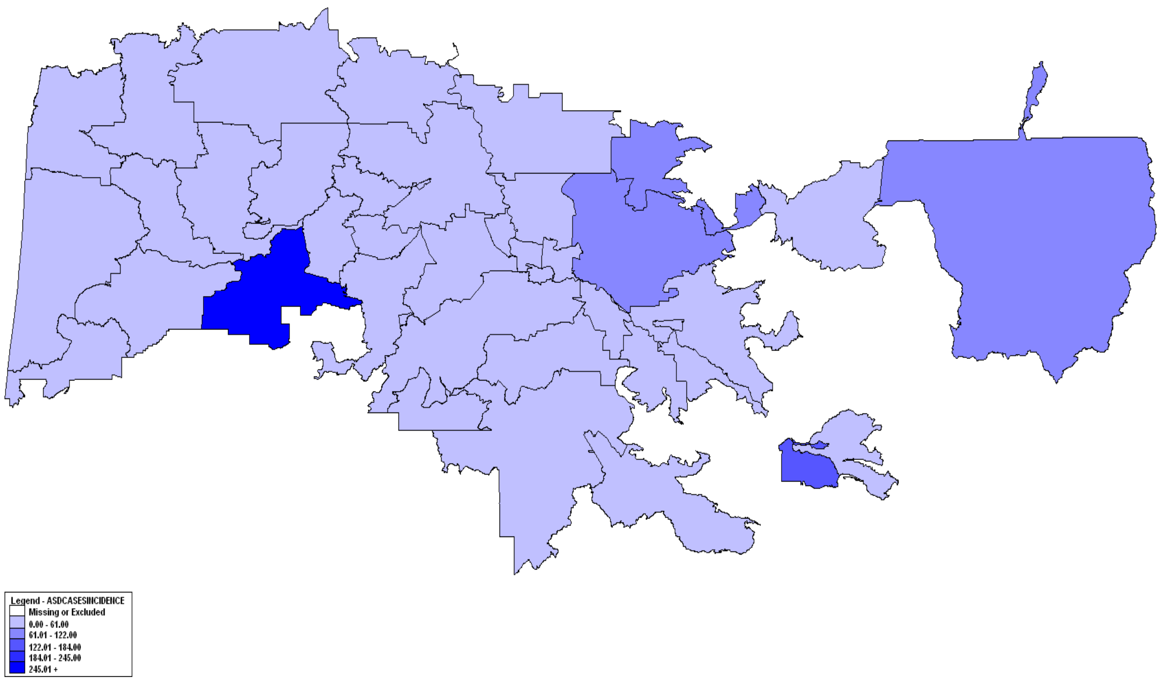

Figure C4. ASD cases by population in Lane County.

Legend

Missing or Excluded
0.01– 61.00
61.00 – 122.00
122.01 – 184.00
184.01 – 245.00
245.01

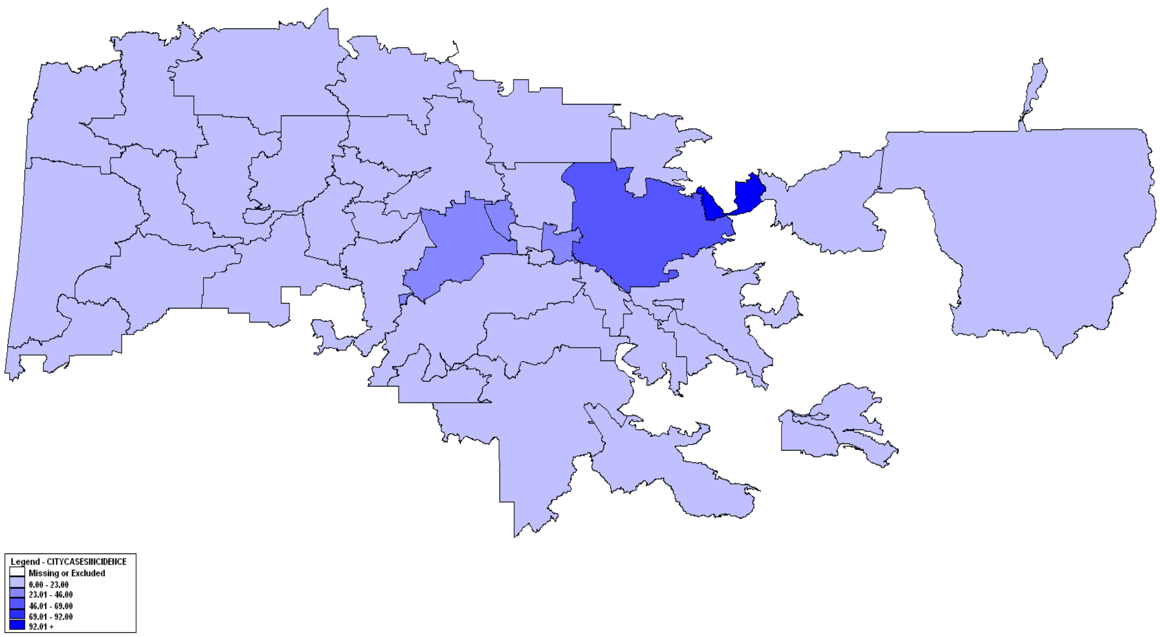

Figure C5. City-sourced water case incidence by population

Legend

Missing or Excluded
0.01– 61.00
61.00 – 122.00
122.01 – 184.00
184.01 – 245.00
245.01

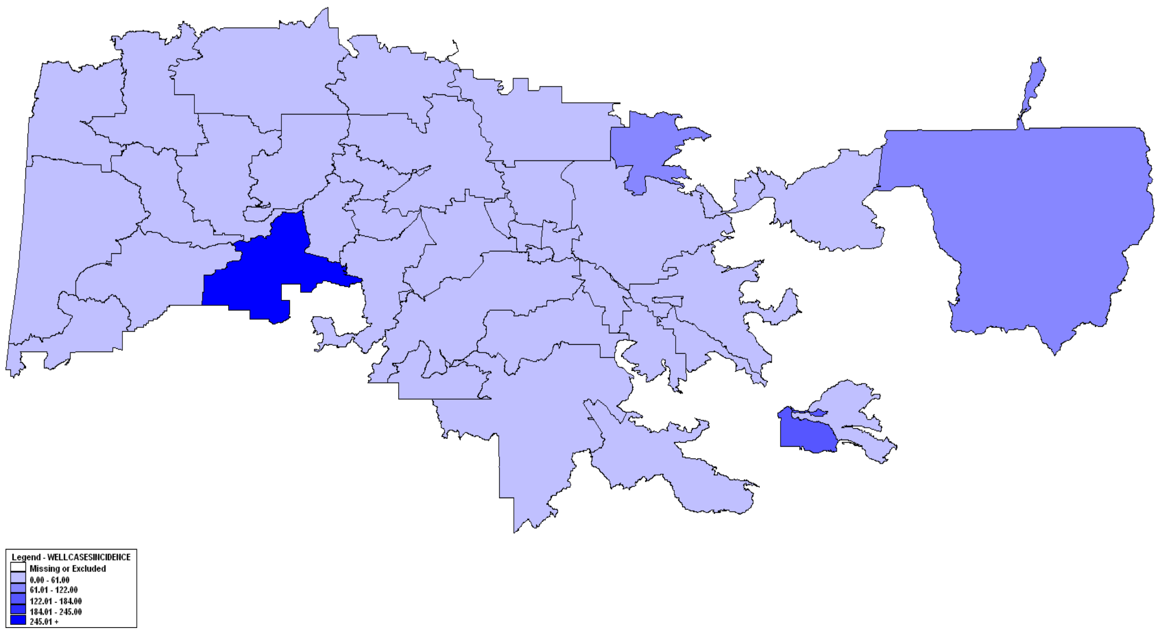

Figure C6. Private-sourced water case incidence by population

Legend

Missing or Excluded
0.01– 61.00
61.00 – 122.00
122.01 – 184.00
184.01 – 245.00
245.01

Appendix D

Data Use Agreement

This Appendix shows the data use agreement obtained in order to use patient level data. Permission was received for use of data collected by Lane County Developmental Disability Services. Patient-level data was obtained from the State of Oregon, Department of Human Services, Lane County Developmental Disabilities Services; this data was on persons currently receiving services through the department.

DATA USE AGREEMENT

This Data Use Agreement, effective as of June 1, 2014, is entered into by and between Sherry Sandreth, Walden University graduate student and Lane County Developmental Disabilities Services. The purpose of this Agreement is to provide Sherry Sandreth with access to a Limited Data Set ("LDS") for use in research in accord with the HIPAA Regulations.

1. Definitions. Unless otherwise specified in this Agreement, all capitalized terms used in this Agreement not otherwise defined have the meaning established for purposes of the "HIPAA Regulations" codified at Title 45 parts 160 through 164 of the United States Code of Federal Regulations, as amended from time to time.

2. Preparation of the LDS. Lane County Developmental Disabilities Services shall prepare and furnish to Sherry Sandreth a LDS in accord with HIPAA Regulations

3. Data Fields in the LDS. No direct identifiers such as names may be included in the Limited Data Set (LDS). In preparing the LDS, Lane County Developmental Disabilities Services shall include the **data fields specified as follows**, which are the minimum necessary to accomplish the research:

   a. Gender, current living situation, whether receiving special education and health coverage, current co-morbidities, co-morbidities at intake, birth year, race, ethnicity, zip code, numerical address number of digits coded 0 or 1, if there was prenatal exposure to drugs or alcohol, and birth place.

4. Responsibilities of Data Recipient. Data Recipient agrees to:

   a. Use or disclose the LDS only as permitted by this Agreement or as required by law;

   b. Use appropriate safeguards to prevent use or disclosure of the LDS other than as permitted by this Agreement or required by law;

   c. Report to Data Provider any use or disclosure of the LDS of which it becomes aware that is not permitted by this Agreement or required by law;

   d. Require any of its subcontractors or agents that receive or have access to the LDS to agree to the same restrictions and conditions on the use and/or disclosure of the LDS that apply to Sherry Sandreth under this Agreement; and

   e. Not use the information in the LDS to identify or contact the individuals who are data subjects.

5. Permitted Uses and Disclosures of the LDS. Sherry Sandreth may use and/or disclose the LDS for its research activities only.

6. Term and Termination.

   a. Term. The term of this Agreement shall commence as of the Effective Date and shall continue for so long as Data Recipient retains the LDS, unless sooner terminated as set forth in this Agreement.

   b. Termination by Data Recipient. Data Recipient may terminate this agreement at any time by notifying the Data Provider and returning or destroying the LDS.

   c. Termination by Data Provider. Data Provider may terminate this agreement at any time by providing thirty (30) days prior written notice to Data Recipient.

   d. For Breach. Data Provider shall provide written notice to Data Recipient within ten (10) days of any determination that Data Recipient has breached a material term of this Agreement. Data Provider shall afford Data Recipient an opportunity to cure said alleged material breach upon mutually agreeable terms. Failure to agree on mutually agreeable terms for cure within thirty (30) days shall be grounds for the immediate termination of this Agreement by Data Provider.

   e. Effect of Termination. Sections 1, 4, 5, 6(e) and 7 of this Agreement shall survive any termination of this Agreement under subsections c or d.

7. Miscellaneous.

   a. Change in Law. The parties agree to negotiate in good faith to amend this Agreement to comport with changes in federal law that materially alter either or both parties' obligations under this Agreement. Provided however, that if the parties are unable to agree to mutually acceptable amendment(s) by the compliance date of the change in applicable law or regulations, either Party may terminate this Agreement as provided in section 6.

   b. Construction of Terms. The terms of this Agreement shall be construed to give effect to applicable federal interpretative guidance regarding the HIPAA Regulations.

   c. No Third Party Beneficiaries. Nothing in this Agreement shall confer upon any person other than the parties and their respective successors or assigns, any rights, remedies, obligations, or liabilities whatsoever.

d. Counterparts. This Agreement may be executed in one or more counterparts, each of which shall be deemed an original, but all of which together shall constitute one and the same instrument.

e. Headings. The headings and other captions in this Agreement are for convenience and reference only and shall not be used in interpreting, construing or enforcing any of the provisions of this Agreement.

IN WITNESS WHEREOF, each of the undersigned has caused this Agreement to be duly executed in its name and on its behalf.

DATA PROVIDER	**DATA RECIPIENT**
Signed: [signature]	Signed: [signature]
Print Name: Andrea Muzikant	Print Name: Sherry Sandreth
Print Title: Program Manager	Print Title: Research Student