UNDERSTANDING CHILDHOOD ENVIRONMENTAL EXPOSURES IN TEXAS WITH A FOCUS ON PESTICIDE EXPOSURES

A Dissertation

by

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ABSTRACT

Through five studies, this dissertation expands our understanding of pesticide exposures and evaluates one intervention for reducing these exposures. The first study assessed the impact of environmental health trainings that addressed multiple exposures for Head Start employees and parents in Webb County, TX. Pre- and post-assessments found significant improvements in knowledge and self-reported behaviors. The remaining studies focused on pesticide exposures. Available literature on pesticide exposures is limited, despite being the eighth most common substance category reported in 2014 to poison centers nationally for children ≤5 years. To fill gaps in the literature, pesticide exposures in children were characterized through descriptive statistics and prevalence calculations for pesticide-related hospitalizations (N=158) and poison center exposures (N=61,147) for children ≤ 19 years in Texas. Males and younger children had a higher prevalence of unintentional exposures, while adolescents had a higher prevalence of intentional exposures. The comparison of hospitalization and poison center data identified trends between the datasets, and discussed dataset strengths and limitations. Finally, an exploratory spatial scan analysis identified primary clusters for unintentional pesticide-related exposures. Descriptive statistics, significance tests, and logistic regression models were used to identify factors associated with clusters of unintentional pesticide-related poison center exposures in children ≤19 years. As the percentile increased for percent black or African American population, the probability of being a cluster county decreased, and as the percentile increased for the percent of the population that had moved in past 12 months, the probability of being a cluster county increased. Lastly, negative binomial regression models identified factors associated with prevalence of unintentional pesticide-related poison center exposures in children ≤19 years. Increasing percentile of American Indian or Alaska Native population was associated with decreased prevalence, and increasing percent of structures built before 1939 was associated with an increased prevalence. This dissertation quantified childhood pesticide exposures and identified related variables. Future research should utilize additional secondary datasets (e.g. cancer registries, mortality data, and emergency room data), and may benefit from the execution of more advanced study designs (e.g. case-control and cohort) that can address the limitations of this dissertation, such as identifying health effects associated with pesticide exposures.

DEDICATION

I dedicate my dissertation research to my family and friends. A special thanks to my loving parents, Daniel and Michele Metts who emotionally supported me throughout my academic endeavors. My sisters Amanda and Alyssa who have mocked me for being a bookworm, but also supported me throughout the program. My grandmother Monica Trueblood, and in memory of my grandfather William R. Trueblood both of whom supported my education and pushed me to excel.

I also dedicate this dissertation to my many friends who have guided me through the many late nights and long weekends of this program. Special thanks and gratitude to Dr. Jennifer Ross, Dr. Scott Robinson, Annamarie Bokelmann, Yolanda McDonald, Ray Weir, Dr. Chidiebere Opara, Dr. Garett Sansom, Lindsay Sansom, Arielle Epstein, and Dr. Heather Reddick.

Lastly, I dedicate this work and give special thanks to my fiancé Sean M. Blakley for being there for me throughout the entire doctoral program for the best and the worst. You have been my greatest supporter and without you, this would not have been feasible. Without the support of all of the mentioned individuals, this dissertation would not have been possible; to them I am forever grateful.

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1. INTRODUCTION

1.1. Introduction

Children encounter many environmental exposures that can impact their health, such as pollutants or contaminants in water, food, soil, and air (indoor and outdoor) (United States Environmental Protection Agency [U.S. EPA] 2015c). Indoor environmental exposures are of particular concern for children who spend most of their time in buildings, such as homes, schools, and day cares (U.S. EPA 2013a). Indoor environmental contaminants of concern come from combustion sources (e.g., furnaces, stoves, fireplaces, and cigarettes), building materials, electronics and toys, cleaning products, pesticides and other products, and biological sources (e.g., dust mites, pet dander, and mold) (U.S. EPA 2013a). An analysis documented $76.6 billion in annual costs in 2008 associated with environmentally related diseases (e.g. lead poisoning, prenatal methylmercury exposure, childhood cancers, asthma, intellectual disability) which is a significant increase from $54.9 billion in 2002 (Trasande and Liu 2011). In the United States, there is a lack of national data on most indoor environmental contaminants with respect to levels of exposure, prevalence of exposures, and potential health effects (U.S. EPA 2013a). In addition, indoor contaminants are not regulated in residential settings (U.S. EPA 2013a). Many residential indoor contaminants are associated with adverse health outcomes (U.S. EPA 2013a). For example, chronic household pesticide exposures are associated with cancers, diabetes, neurobehavioral disorders, birth defects, respiratory problems, and other health effects (Karr et al. 2007; Mostafalou and Abdollahi 2013). In addition, acute health effects associated with household pesticide exposures include nausea, headaches, rashes, eye irritation, and seizures, and in severe cases, death (Karr et al. 2007).

Children are particularly susceptible to environmental health threats due to their behaviors, physiology, and windows of susceptibility (i.e., during fetal development and puberty) (U.S. EPA 2015b). For example, children crawl and play close to the ground; put their hands or toys in their mouths; eat, breathe, and drink more per unit body weight compared to adults; have greater surface area in comparison to their weight; have bodies that are still developing; and experience windows of susceptibility during development (National Pesticide Information Center [NPIC] 2015; U.S. EPA 2015b).

The objectives of this dissertation are: 1) to better understand the impact of environmental trainings on childhood exposures, including common household exposures (e.g., pesticides, lead, and mercury), 2) to characterize and estimate the prevalence of unintentional pesticide exposures in children ≤ 19 years in Texas, 3) to characterize and estimate the prevalence of intentional pesticide exposures in children ≤ 19 years in Texas, and 4) to identify potential health disparities associated with childhood pesticide exposures in children ≤ 19 years. The research will be conducted in accordance with the specific aims described in Section 1.3 below. The dissertation utilizes data obtained through environmental health trainings, as well as secondary data (e.g. hospitalizations and poison center data) obtained from the Texas Department of State Health Services (DSHS).

1.2. Literature Review

1.2.1. Common Environmental Concerns and Children

Children are more at risk from environmental exposures because 1) children are still developing, 2) their organs often cannot remove toxins as well as an adults, 3) infants and children take more breaths per minute which increases their exposure, 4) infants and children have more skin surface compared to body weight, 5) children eat and drink more per unit body weight compared to adults, and 6) infants and young children have behaviors that make them more susceptible, such as crawling on the floor and putting things in their mouths (NPIC 2015; U.S. EPA 2015b). Environmental exposures can occur via food, water, or air; for the purposes of this dissertation, the concern is on residential exposures that affect children (U.S. EPA 2015c). Exposures of concern include pesticides, allergy and asthma triggers, lead, mercury, and other environmental contaminants that may affect health, development, behavior, or growth (National Institute of Environmental Health Sciences [NIEHS] 2011).

According the Centers for Disease Control and Prevention (CDC), 4 million households have children who are exposed to high levels of lead; specifically, 0.5 million children aged 1-5 years old have blood lead levels (BLLs) above 5 µg/dL (CDC 2013b). Levin et al. (2008) found that lead paint and dust account for up to 70% of elevated BLLs, while other sources of lead exposure include soil, folk remedies, pottery, and dietary sources (e.g., breast milk, drinking water, dietary supplements, and imported foods). Lead exposure in general can result in irritability, fatigue, loss of appetite, decreased attention, and insomnia; whereas, lead poisoning in children can result in nervous system damage, behavioral issues, anemia, liver damage, kidney damage, hearing loss, hyperactivity, developmental delays, possibly reduced intelligence quotient (IQ), and potentially death (U.S. EPA 2013b). A second concern is mercury which can be found in some types of fish consumed for food, antiques, batteries, compact fluorescent light bulbs, paints, skin-lightening creams, thermometers, thermostats, and other consumer products (U.S. EPA 2014a). Exposure to mercury can result in tremors, irritability, insomnia, neuromuscular changes, headaches, cognitive function impairment, kidney damage, respiratory damage, and death (U.S. EPA 2014b). A third common concern is asthma and allergy triggers. NIEHS has found that asthma, allergy attacks are increasing, and this is attributed to children spending a majority of their time indoors where they are exposed to allergens from cockroaches, mold, pets, and dust mites (NIEHS 2011). According to the CDC, in the United States approximately 6.8 million children currently have asthma (CDC 2015a). In addition, during a recent 12-month period, 7.8 million children reported respiratory allergies, 4.1 million children reported food allergies, and 8.8 million children reported skin allergies (CDC 2014b).

Fourth, pesticides are commonly used in residential settings because they kill pests that damage plants or homes, threaten public health, and cause other damage (NPIC 2015). According to the United States Environmental Protection Agency (U.S. EPA), a pesticide is any substance that "prevents, destroys, repels, or mitigates a pest, or is a plant regulator, defoliant, desiccant, or nitrogen stabilizer" (U.S. EPA 2015a). In 2007, home and garden pesticide use resulted in approximately 66 million pounds of pesticides being used throughout the United States (Grube et al. 2011). Pesticides are associated with multiple health outcomes, including cancers, birth defects, reproductive disorders, neuro-degenerative diseases, cardiovascular disease, respiratory diseases, diabetes, chronic renal disease, and autoimmune disease (Karr et al. 2007; Mostafalou and Abdollahi 2013). Currently, the estimated annual incidence rate of acute pesticide exposures in schoolchildren is 7.4 per million, which is considered to be a low estimate due to insufficient regulation and lack of surveillance systems resulting in underreporting (Thundiyil et al. 2008). In 2004, the World Health Organization (WHO) estimated that pesticides result in millions of acute poisoning cases per year with approximately 1 million resulting in a hospitalization (WHO 2004). According to the 2014 Annual Report of the American Association of Poison Control Centers' National Poison Data System (AAPCC NPDS), pesticides were the 8th most common substance category reported for children ≤ 5 years for all exposures which is a change from 2009 when pesticides were the 9th most common substance category for the same age group (Bronstein et al. 2010; Mowry et al. 2015). An important component when addressing pesticide and other environmental exposures is intent (unintentional vs. intentional (i.e. self-harm or suicide). For cases reported to poison centers, unintentional exposures are most common for all age groups of children, with the exception of 12 to 19 year olds where a majority of calls are intentional compared to unintentional (58.47% and 36.94, respectively) (Mowry et al. 2015). The remaining calls are for adverse reactions, unknown and other (Mowry et al. 2015). Suicide and self-harm are significant problems worldwide, with suicide being the second most common cause of death in adolescent worldwide; specifically, the research shows that pesticides are frequently used for suicide in rural areas in low-income countries (Hawton et al. 2012).

Other household environmental concerns include carbon monoxide (CO) exposures and household chemicals, including combinations of chemicals that should not be mixed together. In the United States, each year there are about 400 deaths linked to CO poisonings and 20,000 emergency room visits with 4,000 hospitalizations (CDC 2015b). Carbon monoxide poisoning symptoms include headaches, dizziness, weakness, stomachaches, vomiting, chest pain, and can result in death (CDC 2015b). In 2014, the third most common category of pediatric exposures in children under 5 years of age was household cleaning substances, representing 7.68% of calls to poison centers (Mowry et al. 2015). A study using sixteen years of data from 1990-2006 found there were 267,269 children under 5 years of age that were treated in United States emergency rooms due to household cleaning product injuries (McKenzie et al. 2010). The types of injuries reported, but not defined, included poisoning, chemical burns, dermatitis, conjunctivitis, contusions, abrasions, and foreign bodies (McKenzie et al. 2010).

1.2.2. Environmental Educational Trainings and Promotoras

The WHO defines health education as any learning experience that is designed to improve individual or community health through improving knowledge or modifying behaviors (WHO 2015). A meta-analysis conducted by Kok and colleagues found that the mean effect sizes (ES) ranged from 0.46 for primary prevention and 0.49 for secondary prevention and patient education (Kok et al. 1997). The meta-analysis found that health education could be an effective tool for implementing behavior changes (Kok et al. 1997). There is limited evidence on the effectiveness of educational trainings specifically applied to environmental topics or issues, but there is existing evidence that health education can increase knowledge and change behaviors associated with asthma and healthy homes (Carrillo Zuniga et al. 2012). A study addressing asthma and healthy homes found that 98.4% of participants self-reported making changes in their homes following asthma and healthy home training, which supports the occurrence of behavioral changes following educational trainings (Carrillo Zuniga et al. 2012). The study also showed a significant increase in associated knowledge ($p<0.001$) (Carrillo Zuniga et al. 2012).

Promotoras or community health workers (CHWs) are often used in health education due to their ability to connect with and build relationships with community members. The WHO defines CHWs as being members of the communities where they work, who should be responsible to the community where they work, should be selected by the communities, and should complete training that is shorter than a professional program (Lehmann and Sanders 2007). CHWs have been used widely throughout educational trainings, including trainings on diabetes (Lujan et al. 2007; Philis-Tsimikas et al. 2011), cardiovascular disease (Balcázar et al. 2009; Brownstein et al. 2005), cervical cancer (O'Brien et al. 2010), breast cancer (Livaudais et al. 2010), and chronic disease prevention (Hunter et al. 2004; Reinschmidt et al. 2006).

1.2.3. Health Disparities and Environmental Health

The Office of Disease Prevention and Health Promotion (ODPHP), Healthy People defines health disparities as "a particular type of health difference that is closely linked with social, economic, and/or environmental disadvantage. Health disparities adversely affect groups of people who have systematically experienced greater obstacles to health based on their racial or ethnic group; religion; socioeconomic status; gender; age; mental health; cognitive, sensory, or physical disability; sexual orientation or gender identity; geographic location; or other characteristics historically linked to discrimination or exclusion" (ODPHP 2015). The CDC expanded the definition of health disparities to state they result from poverty, inadequate access to health care, individual factors, behavioral factors, educational inequalities, and environmental threats (CDC 2014a). A review paper found that minority populations are disproportionately affected by health care disparities which has been linked to social determinants of health (e.g., education, socioeconomic status, inadequate housing, proximity to environmental hazards) that all contribute to individual and community level health (Thomas 2014).

Previous research has found that adverse environmental health issues are associated with health disparities (Evans and Kantrowitz 2002; Gee and Payne-Sturges 2004; Lee 2002). For example, multiple studies have found evidence that socioeconomic status is linked to pollution exposures and adverse health outcomes (Havard et al. 2009; Laurent et al. 2007; Villeneuve et al. 2003). Havard and colleagues conducted a spatial autocorrelation study to assess environmental equity analyzing traffic-related air pollution and socioeconomic status; this study found a positive association between deprivation index and NO_2 exposure levels (Havard et al. 2009). In addition, a separate study found that there were a multitude of factors that made low-income individuals more susceptible to residential exposures, including: 1) smaller home size which increased the concentration of indoor airborne contaminants, 2) on average, older home age which may cause homes to have increased infiltration from outdoors, and 3) poorer home ventilation in many cases which increases the effect of indoor pollution (Adamkiewicz et al. 2011).

1.2.3.1. Utilization Factors and Environmental Health

Rates of utilization of health care services are a commonly researched health disparity (La Veist 2002). Existing research shows that racial and ethnic minorities have lower rates of utilization (La Veist 2002). This dissertation uses data from poison centers. There are existing studies that indicate there are utilization barriers to poison centers in the United States (Forrester et al. 2005; Litovitz et al. 2010; Vassilev et al. 2006). Vassilev and colleagues (2006) found potential barriers that explain underutilization of poison centers included not speaking English, not knowing the phone number, and not knowing if the poison center could help. A study by Forrester (2005) assessed the association between sociodemographic factors and utilization of poison centers in Texas. This study found that counties with lower utilization rates had higher African-American and Hispanic populations, lower median household incomes, and higher percentage of the population who spoke a language other than English at home. This is supported by a more recent study that addressed determinants of U.S. poison center utilization which found language, being black or African American, distance from poison center, poverty, and lower education levels were barriers to poison center utilization (Litovitz et al. 2010).

Additionally, there are utilization studies that focus specifically on Hispanic and Latino populations. This is important because Texas is unique in that 38.60% of the overall population is Hispanic or Latino, and the population of some counties is more than 90.00% Hispanic or Latino (e.g. Webb County, TX) (Belson et al. 2003; Clark et al. 2002; Otaluka et al. 2015; United States Census Bureau [USCB] 2016). Clark and colleagues (2002) found that areas with higher Latino populations had significantly lower utilization of poison centers. A separate study examined pesticide exposures and poison center use on the Texas-Mexico border found that non-border counties had twice the reported exposure rate of border counties (Belson et al. 2003). Otaluka and colleagues (2015) found that Spanish-speakers were significantly less likely to report that they were aware of poison centers.

1.2.4. GIS and Environmental Health

The CDC defines Geographic Information Systems (GIS) as a collection of technology and science tools that allow us to manage geographic relationships and integrate information, which allows us to analyze spatially referenced data and make decisions based on associations between the geography and data (CDC 2006). GIS has also been defined as analysis and mapping technology that supports information to be analyzed and viewed (Vine et al. 1997).

Existing literature supports the use of GIS in environmental and public health research (Cromley 2003; Jarup 2004; Nuckols et al. 2004; Vine et al. 1997). A review by Cromley (2003) found that GIS tools are commonly used to analyzed factors relating to disease, such as pathological factors, causative agents, vectors, hosts, people, and environments. Vine et al. (1997) is one of the earliest review papers supporting the use of GIS for environmental epidemiology. In this publication, the authors found GIS could be used for linking geographic and non-geographic data, address matching, buffer analysis, and many other functions vital to environmental health research. GIS may also be used for exposure mapping, disease mapping, and as a useful tool throughout the risk assessment process (Jarup 2004). Nuckols et al. (2004) provide several examples of how the combination of experience in geospatial science, epidemiology, and environmental science is required for exposure assessment; specific examples include identifying populations at risk near landfill sites, using GIS to identify potential neurobehavioral effects of exposure to trichloroethylene from water from the municipal water supply, and determining the association between air pollution and lung cancer risk.

1.2.4.1. GIS and Pesticide Research

At this time there is limited research that utilizes GIS methodologies for addressing intentional pesticide exposures; despite this scarcity in the literature, GIS can be used to further improve research associated with intentional pesticide exposures. This section and the next section will discuss existing literature focusing on pesticides and pesticide-related poison center data utilizing GIS methodologies. First, Ward and colleagues (2000) used USDA Farm Service Agency records to help classify satellite images into crop species and locate residences from a case-control study researching non-Hodgkin's lymphoma (NHL). The researchers calculated two things, 1) the distance to the crop fields from each residence, and 2) distance to Toxic Release Inventory (TRI) sites from each residence (Ward et al. 2000). After the researchers accounted for pesticide drift, they estimated 30% of the homes were potentially exposed to agricultural pesticides (Ward et al. 2000). A second review paper examined the existing literature that utilized GIS as a tool for monitoring and understanding pesticide exposures (Kamińska et al. 2004). Specifically, the review paper found that GIS can be used to monitor and model pesticide contamination in water, to analyze pesticide exposures, and to understand the spatial distribution of diseases related to pesticide exposure (Kamińska et al. 2004). A population-based case-control study looked at 1,165 women diagnosed with breast cancer and 1,006 controls from 1988-1995 in Cape Cod, Massachusetts to study the association between pesticide use and breast cancer (Brody et al. 2004). The study geocoded residential addresses and used GIS to conduct exposure assessment of pesticide drift and deposition (Brody et al. 2004). The researchers found no consistent association between breast cancer and pesticide residues, but positive associations were found for family history of breast cancer (OR=1.4, 95% CI 1.2-1.8), increased education (above high school OR=1.5, 95% CI 1.0-2.0), and increased age at first live or stillbirth (OR=1.5, 95% CI 1.2-1.8) (Brody et al. 2004). A more recent publication attempted to reduce the health risks from pesticide exposure by developing personalized exposure assessment through spatial modeling (Leyk et al. 2009). Cornelis and colleagues (2009) developed two indicators to assess pesticide exposure in a case-control study. The two indicators utilized distance-weighted measures, 1) measure of crop area and 2) measure of pesticide use (Cornelis et al. 2009). The researchers calculated both of the indicators for 20 years accounting for residential changes for both cases and controls, but found no difference between the two groups (Cornelis et al. 2009). The existing pesticide and GIS research supports using GIS for exposure assessments, analyzing health effects and potential exposures, and monitoring (Brody et al. 2004; Cornelis et al. 2009; Kamińska et al. 2004; Leyk et al. 2009; Ward et al. 2000).

1.2.4.2. GIS and Pesticide-Related Poison Center Data

There is limited literature utilizing poison center data and GIS methodologies to address pesticide exposures (Sudakin et al. 2002; Sudakin and Power 2009). Sudakin and colleagues (2002) conducted a study to identify regional variation in pesticide exposures through utilizing a space-time scan statistic for 322 cases reported in 2000 in Oregon. The study identified spatial and temporal clusters of pesticide exposures (Sudakin et al. 2002). Next, a more recent study identified regional variation in the severity of pesticide exposures through a spatial scan statistic of 273 cases reported from 2001-2005 in Oregon. This study found clustering of pesticide exposures by severity (Sudakin and Power 2009). Through identifying clusters the researchers believe the information can be utilized for targeted interventions (Sudakin and Power 2009).

1.2.5. Utilizing Hospitalization and Poison Center Data to Address Pesticide-Related Exposures

1.2.5.1. Pesticide-Related Hospitalization Exposure Literature

There is limited literature that has utilized hospitalization data to identify pesticide-related exposures. Mehler and colleagues (2006) utilized hospitalization data, poison center data, and death certificates to evaluate the effectiveness of California Pesticide Illness Surveillance Program (PISP) when ascertaining pesticide exposures. Next, Badakhsh and colleagues (2010) utilized Louisiana hospitalization data to characterize hospitalizations associated with pesticide exposures. The studies were able to characterize pesticide-related hospitalizations through utilization of state level hospital data. Both studies found that younger children and males had higher prevalence of pesticide-related hospitalizations (Badakhsh et al. 2010; Mehler et al. 2006).

1.3. Pesticide-Related Poison Center Literature

Despite being scarce, there are available studies that have utilized poison center data to address pesticide-exposures compared to hospitalization data. First, Spann and colleagues (2000) utilized poison center data to assess the hazards of pesticides and the need of child-resistant packaging. Second, Sudakin and colleagues utilized poison center data in Oregon to attempt to identify spatial clusters (Sudakin and Power 2009; Sudakin et al. 2002). Third, Belson and colleagues (2003) utilized poison center data to address childhood pesticide exposures occurring on the Texas-Mexico border. Next, Sudakin and Power (2007) utilized poison center data to conduct a longitudinal study addressing organophosphate (OPs) exposure. Lastly, Forrester (2013) utilized poison center data to analyze the burden of insecticide chalk on children in Texas.

1.4. Specific Aims

The objectives of this dissertation are: 1) to better understand the impact of environmental trainings on childhood exposures, including common household exposures (e.g., pesticides, lead, and mercury), 2) to characterize and estimate the prevalence of unintentional pesticide exposures in Texas, 3) to characterize and estimate the prevalence of intentional pesticide exposures in Texas, and 4) to identify potential health disparities associated with childhood pesticide exposures. These objectives will be met through the three following specific aims:

1. Assess the changes in knowledge and self-reported behaviors associated with participation in an environmental health training provided for Webb County Head Start Center employees and parents. *This aim is addressed in Section 2 of this dissertation.*
2. Estimate the prevalence of intentional pesticide exposures (e.g., suicide and self-inflicted poisoning) among children age 19 years and under in the state of Texas utilizing the following secondary data: 1) Texas Poison Center pesticide-related calls for 2000-2013 and 2) Texas Inpatient Public Use Data File which includes pesticide-related hospitalizations from 2004-2013. Separate analyses will be done for both datasets. *This aim is addressed in Sections 3, 4, and 5 of this dissertation.*
3. Estimate the prevalence of unintentional pesticide exposures (e.g., accidental ingestion of a pesticide) among children age 19 years and under stratified by demographics (including, gender and age) and other factors (e.g., types of pesticides) using two separate data sets, 1) Texas Poison Center data 2000-2013 and 2) Texas Inpatient Public Use Data File 2004-2013. Examine the potential association of health disparities (including, race/ethnicity, education, insurance coverage, income, rural or urban county classification, and border designation) and unintentional childhood pesticide exposures. Separate analyses will be conducted for both datasets. *This aim is addressed in Sections 3, 4, 5, and 6 of this dissertation*

2. A PILOT STUDY OF CHANGES IN ENVIRONMENTAL KNOWLEDGE AND BEHAVIORS AMONG HEAD START EMPLOYEES AND PARENTS FOLLOWING ENVIRONMENTAL HEALTH TRAINING IN WEBB COUNTY, TX [1]

2.1. Introduction

2.1.1. Population Background

In the United States (U.S), the Latino population is growing rapidly and is predicted to represent 25 % of the population by 2050 (García et al. 2011). The 2010 U.S. Census found 95.7 % of the population of Webb County, Texas (along the U.S.–Mexico border) self-identified as Hispanic or Latino, 91.6 % spoke Spanish as their primary language, and 36.4 % of the population over 25 years old did not complete high school (USCB 2016). Webb County's population is relatively young compared to that of Texas, with the percentage of population under age 18 equal to 34.2 and 26.5 %, respectively (Texas DSHS 2013b).

2.1.2. Environmental Health Background

Communities along the U.S.–Mexico border, including Webb County, encounter economic and health disparities, poor health outcomes, disproportionate environmental threats, and lack of access to environmental information (U.S. EPA 2016c).

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[1] Reprinted with permission from "A Pilot Study of Changes in Environmental Knowledge and Behaviors among Head Start Employees and Parents Following Environmental Health Training in Webb County, TX" by Trueblood A.B., Rincon R., Perales R., Hollingsworth R., Miller C., McDonald T.J., Cizmas L.2016. Journal of Immigrant and Minority Health, 18(1), 135-142, Copyright 2016 by Springer.

Environmental health issues along the U.S.–Mexico border include air pollution, exposure to lead, pesticides, and poor waste disposal services (Carrillo Zuniga et al. 2009). Carter-Pokras and colleagues (2007) provide an excellent review of the multiple environmental exposures Latino children often encounter; such as pesticides, allergens, lead, and mercury. Prevention or reduction of these exposures is vital because Latino children are often more susceptible due to inadequate nutrition, reduced health care access, and other factors faced by children in low-income communities (Carter-Pokras et al. 2007; Institute of Medicine 1999). In Webb County, 3.2 % of children tested had blood lead levels ≥10 μg/dL compared to 2.7 % in South Texas (The Institute for Health Promotion Research n.d.). Another potential exposure is insecticide chalk (Chinese chalk or ‘‘miraculous chalk’’) and methyl parathion (‘‘airplane powder’’), pesticides that are not registered by the U.S. Environmental Protection Agency (USEPA) for home use (Texas DSHS 2014; Forrester 2013). Recent research regarding calls to the Texas Poison Control Centers from 2000–2010 found 188 insecticide chalk exposures from 2000–2010 in children under the age of five (Forrester 2013). This number may be low due to underreporting; households that spoke Spanish were less aware of Poison Control Centers and less likely to have the Poison Control Center’s phone number compared to households that spoke English (Belson et al. 2003). Indoor smoking is common in the border area and is associated with self-reported asthma and respiratory issues (Stephen et al. 2003). Indoor smoking is a source of airborne particulate matter and volatile organic compounds (VOCs) (Stephen et al. 2003).

Another environmental exposure of concern is mercury, due in part to the elevated levels of mercury in certain fish species consumed by humans. Karimi and colleagues (2012) found tuna had a mean mercury level of 0.450 ppm which surpassed the USEPA human health criterion of 0.3 ppm (U.S. Department of Agriculture (USDA) and U.S. Department of Health and Human Services (HHS) 2012). The USDA recommends seafood as a component of a healthy diet due to the nutrients, particularly omega-3 fatty acids (USDA and HHS, 2012). It is important to be aware which fish contain high mercury levels (Karimi et al. 2012; USDA and HHS 2012), particularly for pregnant women and young children. Mercury in fish is an important exposure along the border because fish is a reported staple of meals, especially during the Lenten (Easter) season. Another potential source of mercury is broken fluorescent light bulbs, as household use of compact fluorescent bulbs becomes more common.

Other environmental issues along the border include improper use of bleach, risk of carbon monoxide poisoning due to alternative heating methods, and exposure to asthma and allergy triggers such as dust mites. The U.S.–Mexico Border Health Commission found asthma prevalence and hospitalization rates on the border increased from 1995 to 2000, with asthma incidence increasing from 39.5 to 387.3 per 100,000 population (United States-Mexico Border Health Commission n.d.). Accidental poisonings have been seen in this area as a result of mixing bleach with other cleaning agents, which can create hazardous reaction products such as chlorine gas and chloramines (Nazaroff and Weschler 2004). In addition, carbon monoxide exposure can occur from the use of gas stoves for heating and problems with home heating systems

(Heckerling et al. 1987). A study in the South Bronx, New York found 50 % of the study population used supplemental heating through gas ranges (Sterling and Kobayashi 1981). Research is needed to address household exposures that impact the growing population in this region because many families may not have the resources or knowledge to avoid exposures.

2.1.3. Head Start Centers Background

The Head Start Program is a federal comprehensive child development and early education program that emphasizes parental involvement. The Webb County Head Start Program served approximately 1,300 children aged 3–5 years old during the 2011–2012 fiscal year (Webb County Commissioners Court 2014). Head Start centers provide screenings and services related to health, mental health, nutrition, dental health, and vision that promote proper early childhood development and healthy children (Webb County n.d.).

2.1.4. Study Background

Kok and colleagues found health education can be effective at supporting behavioral changes (Kok et al. 1997). A study by Carrillo Zuniga et al. (2012) in Head Start Centers in Hidalgo County, TX found parents had increased asthma knowledge and changes in self-reported behaviors after health education. Crocker et al. (2011) conducted a systematic review of the evidence on the effectiveness of interventions to improve asthma-related illness which concluded that multicomponent trainings focused on multiple exposures or triggers were effective in reducing asthma.

Existing research on environmental risks and environmental education along the Texas-Mexico border is limited. The purpose of this pilot study was to determine if environmental health training for Head Start parents and employees in Webb County, TX was effective at increasing knowledge and changing behaviors. This study assessed changes in knowledge and self-reported behaviors that influence children's exposure to contaminants including lead, mercury, asthma triggers, and pesticides.

2.2. Methods

2.2.1. Design

The survey design was a panel study that was conducted before and after the environmental health trainings. Knowledge and behavior pre-assessments were given immediately before the training. Knowledge post-assessments were given immediately after training, while behavior post-assessments were given approximately 1 month after the training.

2.2.2. Participants

Environmental health trainings were given to Webb County Head Start Center employees and parents in Webb County, TX in April and May, 2012. Participants were selected using available subject sampling.

2.2.2.1. Employees

All Webb County Head Start employees were required to attend the training for professional development, including teachers, teacher's aides, administrative staff, and janitorial staff. Employees were invited to complete the assessments, but were not required to complete them. Financial compensation was not given to employees for completing the questionnaires.

2.2.2.2. Parents

Webb County Head Start parents were invited to participate in the training and study through letters sent home with their child or children. Parents received a $20 grocery gift card after completion of the final post-assessment for compensation.

2.2.3. Training Material

The training material was designed based on the research team's knowledge of the communities and the existing academic literature. The research team has worked extensively in and around Laredo over the last 13 years, conducting a variety of community outreach, education and intervention projects including hundreds of home-based environmental health assessments. Promotoras (lay health workers) played an important role in these interactions with the community because they were able to engage families in discussions relating to environmental health. The training material included information on sources of exposure to mercury (e.g., certain fish including tuna, mercury-containing skin creams, and broken fluorescent bulbs), lead (e.g., lead-contaminated pottery used for food, folk remedies containing lead, and contaminated candy from Mexico), pesticides, asthma and allergy triggers, carbon monoxide, and hazardous compounds that can be generated by mixing bleach with certain cleaners and chemicals. The multicomponent training included a presentation during which audience questions and discussion were encouraged. There were breakout sessions with hands-on activities, including viewing dust mites through microscopes, seeing two sets of pig lungs that were exposed and not exposed to cigarette smoke, examining a number of household products that could be hazardous, testing the levels of VOCs in personal care and household items using a ppbRAE Plus VOC Detector Monitor (Rae Systems, San Jose, CA), and measuring the composition of particulate matter from a burning candle to examine the health effects of devotional candles. As per the Head Start Program Director's recommendation, trainings were conducted in Spanish for parents, and in English for employees. This was done by bilingual research staff.

2.2.4. Data Collection

Institutional Review Board (IRB) approval for this pilot study was received from the Texas A&M University IRB (Protocol #2012-0017) and the University of Texas Health Science Center—San Antonio IRB (Protocol #12-01-3411). Assessments were collected for inclusion in the study after individuals provided written consent. Pre-and post-assessments were collected by research staff and transported to College Station, TX for data entry and data analysis. Questionnaires were stored in locked file cabinets as approved by the IRB.

2.2.5. Measures

Questionnaires were developed to assess changes in environmental knowledge and behaviors before and after the environmental training. Questionnaires were available in English and Spanish. All Head Start employees except for one completed questionnaires in English and all parents except for two completed questionnaires in Spanish. If a participant elected to complete the questionnaires in a language other than the language of the training, these questionnaires were excluded from the analyses because a preference for the other language indicated a lack of comfort with the language of the training. One employee and two parents were dropped from analysis for this reason. The assessments addressed environmental issues that impact residents of Webb County, TX.

Eleven knowledge questions were used to assess environmental knowledge. The same questionnaire was used before and after the training. The questions consisted of nine true or false questions and two multiple choice questions (Table 1). Two questions measured respondents' knowledge of lead, three assessed knowledge of pesticide use, two evaluated knowledge of proper handling and disposal of fluorescent light bulbs, two addressed knowledge of asthma and allergies, one evaluated participants' knowledge of sources of carbon monoxide, and one assessed the awareness of the hazards of mixing bleach with other cleaners. Each time the questionnaire was administered, the cumulative knowledge score was calculated by assigning one point for each question the participant answered correctly out of a maximum of eleven points.

Ten questions were used to assess changes in environmental behaviors (Table 2). The same behavior questionnaire was used before and after the training. Two questions assessed behaviors that could influence lead exposure among children, three assessed pesticide-associated behaviors, and there was one question for behaviors related to each of the following categories: safe use and handling of fluorescent light bulbs, carbon monoxide, mixing bleach with other cleaners, and the mercury content of fish. The behavior questions consisted of nine nominal questions (yes, no, and don't know) as well

Table 1 Changes in Knowledge among Head Start Employees and Parents following an Environmental Health Education Training in Head Start Centers in Webb County, TX (N=114[a])

Environmental Topic	Question	Desired Answer	Pre-Test (% Correct)	Post-Test (% Correct)	Change (%)	P-Value [bcd]
Lead Exposure	Children can be affected by lead even when they look like they are healthy.	True	98.25	100.00	1.75	0.0279
	Greta or Azarcon folk remedies (also called Rueda, Coral, Maria Luisa, Alarcon or Liga) are safe to use.	False	89.47	96.49	7.02	
Mercury in Fluorescent Light Bulbs	Broken compact fluorescent light bulbs can be safely cleaned up with a vacuum cleaner or broom.	False	83.33	95.61	12.28	0.0000
	Nothing bad happens if you throw compact fluorescent light bulbs in the trash.	False	88.60	95.61	7.01	
Asthma and Allergy Triggers	The following are known asthma triggers, EXCEPT? (Choices: Roaches, Dust Mites, Mold, Walking Barefoot)	Walking Barefoot	75.44	91.23	15.79	0.0000
	Smoking in the car or home may cause allergies and asthma.	True	100.00	98.25	-1.75	

Table 1 Continued

Environmental Topic	**Question**	**Desired Answer**	**Pre-Test (% Correct)**	**Post-Test (% Correct)**	**Change (%)**	**P-Value** [bcd]
Pesticide Exposure and Pest Management	Which one of the following is the safest way to store pesticides? (Choices: In a cabinet that contains food, In a Ziploc bag, In a soda or water bottle, In a high cabinet that children can't reach).	In a high cabinet that children can't reach	98.25	99.12	0.87	0.0000
	Removing materials from crowded countertops helps to eliminate pests.	True	89.47	93.86	4.39	
	Chinese chalk (also called miraculous chalk) is legal for use in the U.S.	False	65.79	91.23	25.44	
Carbon Monoxide	It is safe to use stoves or ovens to help heat the home.	False	94.78	99.12	4.34	1.0
Hazardous Reaction Products from Mixing Bleach with Other Cleaners	Bleach can be safely mixed with other cleaners.	False	85.96	97.37	11.41	0.0016

[a] Employees and parents were combined into one group.
[b] The Bonferroni-adjusted test was done at the 99.38 significance level.
[c] One test was done for each environmental topic to reduce the number of significance tests being conducted.
[d] T-tests were used to assess the significance of the knowledge categories: lead exposure, fluorescent light bulbs, asthma and allergy triggers, and pesticide exposure, while McNemar tests were used for the categories of carbon monoxide and mixing bleach with other cleaners.

as one multiple choice question. The behavior score was determined by adding one point for each correctly answered question out of a maximum of ten points.

2.2.6. Analysis

Statistical analyses were performed using STATA 12.0 (College Station, TX). Paired t tests were used to evaluate the overall effectiveness of the training in terms of knowledge and behaviors gained by parents and employees. Bonferroni adjustment was conducted to control for the large number of significance tests. Paired t tests for continuous data were used to: (1) test for differences between employees and parents; and (2) examine mean differences between pre- and post-test scores to determine effectiveness of the training. McNemar's tests for binary data were conducted to evaluate whether there was a statistically significant difference before and after the training regarding knowledge about carbon monoxide and safe use of bleach (see Table 1, 2). Statistical analysis was conducted using paired t tests and McNemar's tests with Bonferroni adjustments (see Table 1, 2 footnotes for specific test used for each item). Tabulations were done to determine percent change in correct responses between the pre- and post-tests (see Tables 1, 2). Head Start employees and parents were combined for the analyses because no differences were observed between the two groups in the responses on these questionnaires when t tests were conducted (data not shown). All statistical tests of significance were two-sided, with significance set at $p < 0.05$. Due to a limited source of identifying variables, a complete case analysis was carried out on these participants to avoid potential bias. The data were analyzed only for 114 individuals (64

Table 2 Changes in Behavior among Head Start Employees and Parents following an Environmental Health Education Training in Head Start Centers in Webb County, TX (N=114[a])

Environmental Topic	Question	Desired Answer	Pre-Test (% Correct)	Post-Test (% Correct)	Change (%)	P-Value [bcd]
Lead Exposure	In the future, when you are caring for a child outside of school, and the child has empacho or teething problems: would you give them Greta or Azarcon (folk remedies that are also called Rueda, Coral, Maria Luisa, Alarcon, or Liga)?	No	85.09	98.25	13.16	0.0000
	Have you given a child tamarind pulp in a glazed bowl in the past month?	No	92.98	99.12	6.14	
Mercury in Fish	Do you consider the mercury content of fish before buying it for your family?	Yes	42.11	72.81	30.07	0.0000
Mercury in Fluorescent Light Bulbs	If a compact fluorescent light bulb breaks, do you clean it up with a broom or vacuum?	No or Don't use compact florescent light bulbs	72.81	92.98	20.17	0.0008
Asthma and Allergy Triggers	In the past month, has anyone smoked inside your home?	No	95.61	98.25	2.64	1.00

Table 2 Continued

Environmental Topic	**Question**	**Desired Answer**	**Pre-Test (% Correct)**	**Post-Test (% Correct)**	**Change (%)**	**P-Value** [bcd]
Pesticide Exposure and Pest Management	Which rooms does your family eat in? Check all that apply.	Kitchen; and/or Dining Room and/or Outside	64.91	81.59	16.68	
	Do you store pesticides or cleaning products in unlocked cabinets that are close to the floor in rooms where children may be present?	No	82.46	92.98	10.52	0.0000
	Do you plan to use Chinese chalk (also called miraculous chalk) when you have pest problems?	No	89.47	99.12	9.65	
Carbon Monoxide	When it is cold, would you use a stove, oven or charcoal grill to heat your home?	No	97.37	100.00	2.63	1.00
Hazardous Reaction Products from Mixing Bleach with Other Cleaners	In the past month have you used bleach mixed with other cleaners?	No	77.19	93.86	16.67	0.0005

[a] Employees and parents were combined into one group.
[b] The Bonferroni-adjusted test was done at the 99.38 significance level.
[c] One test was done for each environmental topic to reduce the number of significance tests being conducted.
[d] T-tests were used to assess the significance of the behavior categories: lead exposure, mercury and fish, fluorescent light bulbs, and pesticide exposure, while McNemar tests were used for the categories of asthma and allergy triggers, carbon monoxide, and mixing bleach with other cleaners.

parents and 50 employees) who completed all questionnaires in the same language as the training they received.

2.3. Results

2.3.1. Responses to Knowledge Items

The paired t test showed that the increase in the knowledge scores from the pre- to the post-assessments was significant ($p < 0.05$) (Table 3). The mean difference between the pre- and post-assessments of knowledge was 0.89. For the knowledge questionnaire, the mean pre-training score out of eleven points was 9.69, 95 % CI [9.44, 9.94] and the mean post-training score was 10.58, 95 % CI [10.42,10.74]. A significant difference was found between the knowledge pre- and post-assessments for the categories of lead exposure, mercury in fluorescent light bulbs, asthma and allergy triggers, pesticide exposure and pest management, and hazardous reaction products from mixing bleach with other cleaners (Table 1).

Table 3 Summary of Pre- and Post-Test Scores among Head Start Employees and Parents[a]

	Pre-Test		Post-Test		
	Mean Score	**95% CI**	**Mean Score**	**95% CI**	**T-test P-Value**
Knowledge	9.69	(9.44, 9.94)	10.58	(10.42, 10.74)	<0.0000
Behavior	8.00	(7.71, 8.29)	9.29	(9.10, 9.48)	<0.0000

[a] There were 11 maximum points for the knowledge assessment and 10 maximum points for the behavior assessment.

2.3.2. Responses to Behavioral Items

The behavior scores of the Head Start employees and parents also increased significantly between the pre-and post-assessments ($p < 0.05$) (Table 3). The mean difference between pre- and post-assessments of behavior was 1.29. The mean pre-training score out of ten points was 8.00, 95 % CI [7.71, 8.29] while the mean post-training score was 9.29, 95 % CI [9.10, 9.48]. There were also significant differences between the pre- and post-assessments for behaviors relating to lead, pesticides, mercury in fish and fluorescent light bulbs, and hazardous reaction products from mixing bleach with other cleaners (Table 2).

The results indicate that following the training, knowledge and self-reported behaviors related to environmental exposures were improved among the Webb County Head Start employees and parents. The highest percent increase in knowledge scores was found in the questions focusing on known asthma triggers (15.79 %), Chinese chalk (25.44 %), mixing bleach with other chemicals (11.41 %), and cleaning broken fluorescent light bulbs (12.28 %). The highest percent increase in behavior scores occurred in the questions on folk remedies that contain lead (13.16 %), mercury in fish (30.07 %), safe handling and disposal of fluorescent light bulbs (20.17 %), where family eats/pest management (16.68 %), and hazardous reaction products from mixing bleach with other cleaners (16.67 %).

2.4. Discussion and Conclusions

Discussions of environmental justice have centered on siting of polluting and/or potentially hazardous operations in low-income and minority neighborhoods; however, these neighborhoods also frequently experience heightened environmental exposures at the household level (Preston et al. 2000). The results of the present study suggest that the environmental health training for Head Start employees and parents increased environmental knowledge and improved behaviors that influence environmental exposures among children. Previous literature supports our findings that multicomponent trainings focused on multiple exposures or triggers are effective for improving environmental health (Crocker et al. 2011). The Healthy Home project in Rochester, New York found that educating visitors on environmental hazards was successful at reducing household hazards and helped visitors develop strategies to reduce exposures (Korfmacher and Kuholski 2008). A second study by Lichtenstein and colleagues (2000) found a combination of telephone counseling and a video resulted in increased household smoking bans 12 months after the intervention. These studies support our findings that increased knowledge through education, as well as discussion of possible environmental health solutions, may improve self-reported behaviors (Lichtenstein et al. 2000).

The study results support that Head Start centers are ideal collaborators for programs to reach parents and employees who can influence environmental exposures among young children. This is supported by previous literature which found that asthma health education can impact knowledge and behaviors in Head Start parents (Carrillo Zuniga et al. 2012). A separate study found that a home visitor injury prevention program offered to Head Start families in the state of Washington was effective at improving knowledge and behaviors associated with poisons in the home, and proper use of smoke detectors and child safety restraints in cars (Johnston et al. 2000). Another study by Piziak (2012) found that a bilingual pictorial nutrition education game offered in Head Start populations resulted in increased vegetables offered throughout the week. To our knowledge, the present study is the first in published literature to provide information on knowledge and behavior changes following training on a wide range of environmental exposures in South Texas. This information can be used in the development of future environmental health interventions along the Texas-Mexico border.

A limitation of this pilot project was that demographic information was not collected, which would have made it possible to assess if there was a relationship between socioeconomic factors or other factors and knowledge or behaviors relating to environmental exposures. Another limitation was that due to funding constraints, the trainings could only be offered in one language at a time. Employees were trained in English and parents in Spanish. The trainings were the same; only the language was different. This resulted in the elimination of three participants from the final analysis, and may have reduced the study's overall response rate. Next, participants may not have been representative of all parents and employees because they were self-selected. Another limitation is potential differential misclassification between employees and parents which was addressed by analyzing the groups separately. This found there were no differences between the groups. This may have been related to a small sample size which was impacted by a low completion rate. Out of 560 individuals who attended the training, only 114 completed all questionnaires in the language of the training. Lastly, the behaviors were self-reported which may have potentially led to recall bias.

Due to the growth of the Latino population in the U.S., it is vital that future research be conducted. Future research should determine if potential confounders, such as age, gender, or willingness to participate in health education, would impact knowledge and behavior outcomes. Research should be conducted to determine if environmental training for adults is effective at reducing actual environmental exposures experienced by children. Lastly, many Head Start parents and employees had knowledge and behavior scores on the pre-assessment that were higher than expected. Future trainings should tailor the educational content to the population.

3. PESTICIDE-RELATED HOSPITALIZATIONS IN CHILDREN IN TEXAS, 2004-2013[2]

3.1. Introduction

Children are susceptible to environmental health threats due to their behaviors, physiology, and windows of susceptibility (e.g., fetal development and puberty) (U.S. EPA 2015b). Children crawl and play close to the ground; put their hands or toys in their mouths; eat, breathe, and drink more per unit body weight compared to adults; have greater surface area in comparison to their weight; have natural defenses that are less developed compared to adults; and encounter windows of susceptibility during development (NPIC, 2015; U.S. EPA 2015b). Children encounter many exposures that can impact their health, such as pollutants or contaminants in water, food, air, and soil (U.S. EPA 2015c).

Pesticides are defined by the U.S. Environmental Protection Agency as any substance that "prevents, destroys, repels, or mitigates a pest, or is a plant regulator, defoliant, desiccant, or nitrogen stabilizer" (U.S. EPA 2015a). In 2007, home and garden use resulted in approximately 66 million pounds of pesticides residentially applied throughout the United States (U.S) (Grube et al. 2011). Acute pesticide exposures are associated with many health effects including nausea, headaches, rashes, eye irritation, seizures, and death (Karr et al. 2007). Chronic pesticide exposures are associated with

[2] Reprinted with permission from "Pesticide-Related Hospitalizations in Children in Texas, 2004-2013" by Trueblood A.B., Shipp E.M., Han D., Ross J., Cizmas L.H. Public Health Reports, Accepted 4/29/2016, Copyright 2016 Association of Schools of Public Health.

health effects, including cancers, birth defects, reproductive disorders, neuro-degenerative diseases, cardiovascular disease, respiratory diseases, diabetes, chronic renal disease, and autoimmune disease (Karr et al. 2007; Mostafalou and Abdollahi 2013). The purpose of this study was to characterize pesticide-related hospitalizations in Texas for children age ≤ 19 years. The study analyzed hospitalizations by intent (unintentional or intentional exposure), sex, age, and pesticide classification. Hospitalization data has been utilized in the U.S. to address pesticide-related hospitalizations, but to our knowledge, this paper is the first addressing childhood pesticide-related hospitalizations in Texas (Badakhsh et al. 2010; Mehler et al. 2006).

3.2. Methods

3.2.1. Data Collection

Data were obtained from the Texas Health Care Information Collection (THCIC) Texas Inpatient Public Use Data File (PUDF) for 2004-2013, which contains data on hospital discharges (Texas DSHS 2015b). The dataset includes information on patient age, sex, race, ethnicity, length of stay, admission status, severity, diagnoses, cost of hospitalization, and payer information (Texas DSHS 2015b). Diagnoses are based on the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM).

Pesticide-related ICD-9-CM codes and E-codes were selected based on the National Institute for Occupational Safety and Health (NIOSH) Pesticide Program and previous literature (Badakhsh et al. 2010; Mehler et al. 2006; NIOSH 2005). ICD-9-CM codes assign codes for diagnoses in U.S. hospitals; whereas E-codes are used to classify injury by intent (e.g., unintentional, homicide/assault, suicide/self-harm, undetermined) and mechanism (e.g., poisoning, motor vehicle) (CDC 2009; CDC 2013a). Table 4 defines pesticide-related codes and the frequency of each code. Cases were classified as hospitalizations due to unintentional pesticide exposures if the code was not suicide or self-inflicted (e.g., E-codes 950.0-E950.9). E-code 861.4 (disinfectants) is included as a pesticide-related code because disinfectants are regulated under Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) as pesticides (Mehler et al. 2006). Hospitalizations due to intentional exposures were defined using two parameters: 1) records with E-code 950.6 (suicide or self-inflicted harm by agricultural and horticultural chemical and pharmaceutical preparations other than plan foods and fertilizers) and 2) records with non-pesticide suicide and self-inflicted harm codes (E950.0-E950.5 and E950.7-E950.9) that were used with a pesticide-related ICD-9-CM code. (Badakhsh et al. 2010; Mehler et al. 2006; NIOSH 2005).

Table 4 Frequency of ICD-9-CM[a] and E-codes by Percent of Cases for Pesticide-Related[b] Hospitalizations for Children age ≤ 19 years in Texas, 2004-2013 (n=158)

Code	Code Definition	Number of times code reported[c]	Percent of cases [d]
ICD-9-CM or E-codes			
989.4	Toxic Effect of Other Pesticides Not Elsewhere Classified	89	56.3
E950.6	Suicide and Self-Inflicted Poisoning by Agricultural and Horticultural Chemical and Pharmaceutical Preparations Other than Plant Foods and Fertilizers	30	19.0
989.3	Toxic Effect of Organophosphate and Carbamate	28	17.7
E861.4	Accidental Poisonings by Disinfectants	25	15.8
E863.7	Accidental Poisoning by Rodenticides	25	15.8
E863.4	Accidental Poisoning by Other and Unspecified Insecticides	22	13.9
E863.1	Accidental Poisoning by Insecticides of Organophosphorus Compounds	16	10.1

Table 4 Continued

Code	Code Definition	Number of times code reported[c]	Percent of cases [d]
E950.0-E950.5; E950.7-E950.9	Suicide and Self-Inflicted poisoning with a pesticide-related ICD-9-CM code	13	8.2
E863.6	Accidental Poisoning by Fungicides	12	7.6
E980.7	Poisoning by Agricultural and Horticultural Chemical and Pharmaceutical Preparations Other than Plant Foods and Fertilizers Undetermined Whether Accidentally or Purposely Inflicted	7	4.4
989.2	Toxic Effect of Chlorinated Hydrocarbons	6	3.8
989.0	Toxic Effect of Hydrocyanic Acid and Cyanides	4	2.5
E863.0	Accidental Poisoning by Insecticides of Organochlorine Compounds	3	1.9
E863.3	Accidental Poisoning by Mixtures of Insecticides	2	1.3
E863.2	Accidental Poisoning by Carbamates	1	0.6
989.1	Toxic Effect of Strychnine and Salts	0	0.0
E863.5	Accidental Poisoning by Herbicides	0	0.0
E863.8	Accidental Poisoning by Fumigants	0	0.0
E863.9	Accidental Poisoning by Other and Unspecified Agricultural and Horticultural Chemical and Pharmaceutical Preparations Other Than Plant Foods and Fertilizers	0	0.0

[a] International Classification of Diseases, Ninth Revision
[b] External cause of injury or poisoning code
[c] Sum of the number of codes is greater than number of cases (N=158) because some cases included multiple pesticide-related ICD-9-CM and E-codes.
[d] Sum of the percentages is greater than 100 because some cases included multiple pesticide-related ICD-9-CM and E-codes.

Variables in the analysis included year of hospitalization, patient demographics (age, sex, race, and ethnicity), county, principle diagnosis code, all 24 other diagnosis codes, and all 10 E-codes. In all cases, children were defined as being age 19 years or younger. Age was classified into three categories, ≤ 4 years old, aged 5 to 14 years, and aged 15 to 19 years. Next, based on previous research by Badakhsh and colleagues, a pesticide classification variable was created based on the most specific pesticide code reported (Badakhsh et al. 2010). For example, if the ICD-9-CM code was 989.4 (other pesticide) and the E-code was E863.7 (rodenticides), the case was coded as rodenticide. Categories used for classification were based on the chemical categories in the ICD-9-CM and E-codes, including disinfectants; fumigants; fungicides; herbicides; hydrocyanic acid and cyanides; rodenticides; chlorinated hydrocarbons; strychnine and salts; organochlorines; organophosphates/carbamates; and other pesticides. Codes used to indicate other pesticides included 989.4, E863.3, E863.4, and E980.7. Organochlorines and chlorinated hydrocarbons were both classified as organochlorines. Illness severity was used to assess severity of the outcome using the All Patient Refined (APR) Diagnosis Related Group (DRG) from the 3M APR-DRG (Texas DSHS 2013). APR-DRG classifies individuals with multiple comorbid conditions or issues that involve multiple organs as higher severity of illness (Averill et al. 2003b). Each patient receives their own severity of illness score due to distinct patient attributes (i.e., different susceptibility and comorbid conditions) (Averill et al. 2003b). Population data for children age ≤ 19 years was obtained from the USCB using 2010 decennial data (USCB 2016).

3.2.2. Data Analysis

This research was deemed exempt by the Texas A&M Institutional Review Board (IRB) (Study #2015-0563M). SAS 9.4 was used for data management and descriptive statistics (SAS Institute Inc., Cary, NC). Prevalence was calculated for age categories, sex, and total cases for hospitalizations related to both intentional and unintentional pesticide exposures. Microsoft Excel 2013 was used for prevalence calculations (Microsoft Corporation, Redmond, WA). Pesticide-related hospitalization prevalence and 95% confidence intervals (CIs) were calculated for Texas, and then stratified by hospitalizations due to unintentional exposures, hospitalizations due to intentional exposures, pesticide classification, and illness severity. Age-specific and sex-specific prevalence were calculated.

3.3. Results

3.3.1. Frequency of Pesticide Diagnoses Codes

There were 158 pesticide-related hospitalizations identified using ICD-9-CM and E-codes (Table 4). The two most common ICD-9-CM codes were 989.3 (organophosphates/carbamates) and 989.4 (other pesticide); the frequency of these two codes was 28 (17.72%) and 89 (56.33%) cases, respectively. The four most common E-codes were E950.6 (suicide and self-inflicted poisoning associated with pesticides), E861.4 (disinfectants), E863.7 (rodenticides), and E863.4 (other pesticides). These codes were used for 30 (18.99%), 25 (15.82%), 25 (15.82%), and 22 (13.92%) cases, respectively.

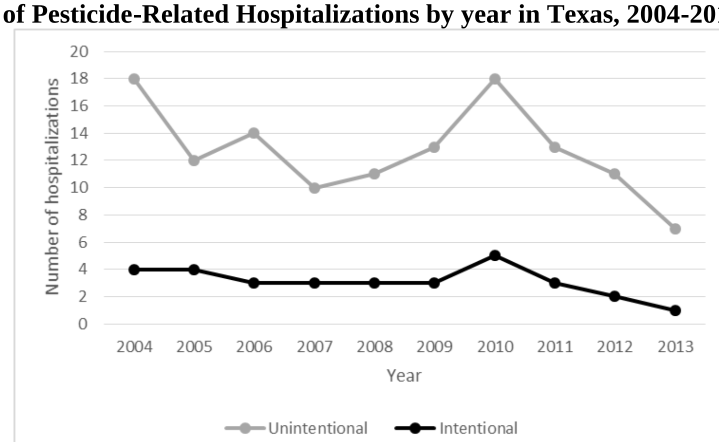
3.3.2. Utility of ICD-9-CM Codes and E-Codes for Identification of Cases

Through utilizing ICD-9-CM codes alone, 75.59% of hospitalizations due to unintentional pesticide exposures were identified. The remaining 24.41% were identified with E-codes. Through utilizing E-codes alone, 86.61% of hospitalizations due to unintentional pesticide exposures would have been identified, with an additional 13.39% identified with ICD-9-CM codes. For hospitalizations due to intentional pesticide exposures, E-codes were utilized first because they are used to classify injury by intent (e.g., unintentional or intentional). By using E-code 950.6, 96.77% of hospitalizations due to intentional pesticide exposures were identified. The remaining hospitalizations due to intentional exposures were identified using E-codes 950.0-950.5 or 950.7-950.9 with a pesticide-related ICD-9-CM code.

3.3.3. Pesticide-related Hospitalization Prevalence

Of the 158 pesticide-related hospitalizations, the average annual number of cases was 15.8 with a range of 8 to 23 cases for children age ≤ 19 years (Figure 1). Pesticide-related hospitalization prevalence is presented in Table 5. The prevalence for the state of Texas for children was 2.07 per 100,000 (95% CI 1.75, 2.40). Sex-specific prevalence for males and females were 2.67 per 100,000 (95% CI 2.15, 3.18) and 1.45 per 100,000 (95% CI 1.06, 1.84), respectively. The age-specific prevalence for children ≤ 4 years, children aged 5 to 14 years, and children aged 15 to 19 years were 5.34 per 100,000 (95% CI 4.31, 6.37), 0.29 per 100,000 (95% CI 0.12, 0.46), and 2.34 per 100,000 (95% CI 1.65, 3.03), respectively.

Figure 1 Number of Pesticide-Related Hospitalizations by year in Texas, 2004-2013



3.3.4. Hospitalizations Due to Unintentional Pesticide Exposures

From 2004-2013, among children age ≤ 19 years in Texas, there were 127 pesticide-related hospitalizations due to unintentional pesticide exposures. The average number of hospitalizations due to unintentional exposures was 12.7 cases per year with a range of 7 to 18 cases per year (Figure 1). The prevalence of hospitalizations due to unintentional pesticide exposures was 1.67 per 100,000 (95% CI 1.38, 1.96) (Table 5). Sex-specific prevalence calculations for unintentional exposures was 2.26 per 100,000 (95% CI 1.79, 2.73) for males and 1.05 per 100,000 (95% CI 0.72, 1.38) for females. Next, age-specific prevalence was 5.34 per 100,000 (95% CI 4.31, 6.37) for children age 0 to 4 years, 0.24 per 100,000 (95% CI 0.08, 0.39) for children aged 5 to 14 years old, and 0.80 per 100,000 (95% CI 0.39, 1.20) for children aged 15 to 19 years old.

3.3.5. Hospitalizations Due to Intentional Pesticide Exposures

There were 31 pesticide-related hospitalizations due to intentional exposures among children age ≤ 19 years. The average prevalence of hospitalizations due to intentional pesticide exposures was 3.1 cases per year with a range of 1 to 5 cases annually (Figure 1). The prevalence of hospitalizations due to intentional pesticide exposures is shown in Table 5, and the prevalence for children age ≤ 19 years was 0.41 per 100,000 (95% CI 0.26, 0.55). The sex-specific prevalence for males and females was 0.41 per 100,000 (95% CI 0.21, 0.61) and 0.40 per 100,000 (95% CI 0.20, 0.61), respectively. The highest prevalence was seen among children aged 15 to 19 years old (1.54 per 100,000; 95% CI 0.98, 2.10), while the age-specific prevalence for children aged 5 to 14 years old was 0.05 per 100,000 (95% CI -0.02, 0.13).

Table 5 Frequency and Prevalence of Pesticide-Related Hospitalizations for Children age ≤ 19 years in Texas by Gender, Age, and Illness Severity[a] in Texas,2004-2013

	Number of cases	Percent of cases	Population Size[b]	Prevalence per 100,000	95% CI
All Pesticide-Related Hospitalizations					
Total	158	100.0	7,621,714	2.1	1.8,2.4
Males	104	65.8	3,899,515	2.7	2.2,3.2
Females	54	34.2	3,722,199	1.5	1.1,1.8
0 to 4 years old	103	65.2	1,928,473	5.3	4.3,6.4
5 to 14 years old	11	7.0	3,810,117	0.3	0.1,0.5
15 to 19 years old	44	27.9	1,883,124	2.3	1.7,3.0
Minor Illness Severity	86	54.4	7,621,714	1.1	0.9,1.4
Moderate Illness Severity	40	25.3	7,621,714	0.5	0.4,0.7
Major Illness Severity	21	13.3	7,621,714	0.3	0.2,0.4
Extreme Illness Severity	11	7.0	7,621,714	0.1	0.1,0.2
Hospitalizations Due to Unintentional Pesticide Exposure					
Total	127	100.0	7,621,714	1.7	1.4,2.0
Males	88	69.3	3,899,515	2.3	1.8,2.7
Females	39	30.7	3,722,199	1.1	0.7,1.4
0 to 4 years old	103	81.1	1,928,473	5.3	4.3,6.4
5 to 14 years old	9	7.1	3,810,117	0.2	0.1,0.4
15 to 19 years old	15	11.8	1,883,124	0.8	0.4,1.2
Minor Illness Severity	71	55.9	7,621,714	0.9	0.7,1.2
Moderate Illness Severity	31	24.4	7,621,714	0.4	0.3,0.6
Major Illness Severity	15	11.8	7,621,714	0.2	0.1,0.3
Extreme Illness Severity	10	7.9	7,621,714	0.1	0.1,0.2
Hospitalizations Due to Intentional Pesticide Exposure					
Total	31	100.0	7,621,714	0.4	0.3,0.6
Males	16	51.6	3,899,515	0.4	0.2,0.6
Females	15	48.4	3,722,199	0.4	0.2,0.6
0 to 4 years old	0	0.0	1,928,473	0.0	0.0,0.0
5 to 14 years old	2	6.5	3,810,117	0.1	-0.0,0.1
15 to 19 years old	29	93.6	1,883,124	1.5	1.0,2.1
Minor Illness Severity	15	48.4	7,621,714	0.2	0.1,0.3
Moderate Illness Severity	9	29.1	7,621,714	0.1	0.0,0.2
Major Illness Severity	6	19.4	7,621,714	0.1	0.0,0.1
Extreme Illness Severity	1	3.2	7,621,714	0.0	0.0,0.0

[a] Illness severity is based on the 3M All Patient Refined Diagnosis Related Group

[b] Population data for children age ≤ 19 years was obtained from the United States Census Bureau (USCB) using 2010 decennial data.

3.3.6. Illness Severity

The percentages of hospitalizations with illness severity reported as minor, moderate, major, and extreme was 54.43%, 25.32%, 13.29%, and 6.96%, respectively (Table 5). The crude prevalence was 1.13 per 100,000 (95% CI 0.89, 1.37) for minor illness severity for all hospitalizations. The prevalence for moderate, major, and extreme illness severity were 0.52 per 100,000 (95% CI 0.36, 0.69); 0.28 per 100,000 (95% CI 0.16, 0.39); and 0.14 per 100,000 (95% CI 0.06, 0.23), respectively. Similar percentages were observed for hospitalizations due to unintentional pesticide exposures, in which the prevalence for minor, moderate, major, and extreme illness severity were 0.93 per 100,000 (95% CI 0.71, 1.15); 0.41 per 100,000 (95% CI 0.26, 0.55); 0.20 per 100,000 (95% CI 0.10, 0.30); and 0.13 per 100,000 (95% CI 0.05, 0.21), respectively. The prevalence of hospitalizations due to intentional exposures for minor, moderate, major, and extreme illness severity was 0.20 per 100,000 (95% CI 0.10, 0.30), 0.12 per 100,000 (95% CI 0.04, 0.20), 0.08 per 100,000 (95% CI 0.02, 0.14), and 0.01 per 100,000 (95% CI -0.01, 0.04), respectively. In addition, the study identified four deaths for the time period (data not shown).

3.3.7. Pesticide Classification

Next, all hospitalizations were classified into a new variable for pesticide class based on the most specific pesticide ICD-9-CM and E-code provided. The most common categories (≥ 15% of cases) included other pesticides (36.71%), organophosphates/carbamates (17.72%), disinfectants (15.82%), and rodenticides (15.82%) (Table 6).

The prevalence values for these categories were 0.76 per 100,000 (95% CI 0.57, 0.96) for other pesticide, 0.37 per 100,000 (95% CI 0.23, 0.50) for organophosphates/carbamates, 0.33 per 100,000 (95% CI 0.20, 0.46) for disinfectants, and 0.33 per 100,000 (95% CI 0.20, 0.46) for rodenticides. For hospitalizations due to unintentional pesticide exposures, the categories with the highest prevalence were other pesticides (29.13%; 0.49 per 100,000, 95% CI 0.33, 0.64), disinfectants (19.69%; 0.33 per 100,000, 95% CI 0.20, 0.46), rodenticides (19.69%; 0.33 per 100,000, 95% CI 0.20, 0.46), and organophosphates/carbamates (16.54%; 0.28 per 100,000, 95% CI 0.16, 0.39) (Table 6). The highest prevalence for hospitalizations due to intentional pesticide exposures were other pesticide (67.74%; 0.28 per 100,000, 95% CI 0.16, 0.39) and organophosphates/carbamates (22.58%, 0.09 per 100,000, 95% CI 0.02, 0.16).

Table 6 Frequency and Prevalence of Pesticide-Related Hospitalizations by Percent of Cases for Children age ≤ 19 years by Pesticide Classification in Texas, 2004-2013

Classification	Number of cases	Percent of cases	Prevalence per 100,000	95% CI
All Pesticide-Related Hospitalizations				
Other Pesticide	58	36.7	0.8	0.6,1.0
Organophosphates/Carbamates	28	17.7	0.4	0.2,0.5
Disinfectants	25	15.8	0.3	0.2,0.5
Rodenticides	25	15.8	0.3	0.2,0.5
Fungicides	12	7.6	0.2	0.1,0.3
Organochlorines	6	3.8	0.1	0.0,0.1
Hydrocyanic acid and cyanides	4	2.5	0.1	0.0,0.1
Hospitalizations Due to Unintentional Pesticide Exposure				
Other Pesticide	37	29.1	0.5	0.3,0.6
Disinfectants	25	19.7	0.3	0.2,0.5
Rodenticides	25	19.7	0.3	0.2,0.5
Organophosphates/Carbamates	21	16.5	0.3	0.2,0.4

Table 6 Continued

Classification	Number of cases	Percent of cases	Prevalence per 100,000	95% CI
Fungicides	12	9.5	0.2	0.1,0.3
Hydrocyanic acid and cyanides	4	3.2	0.1	0.0,0.1
Organochlorines	3	2.4	0.0	0.0,0.1
Hospitalizations Due to Intentional Pesticide Exposure				
Other Pesticide	21	67.7	0.3	0.2,0.4
Organophosphates/Carbamates	7	22.6	0.1	0.0,0.2
Organochlorines	3	9.7	0.0	0.0,0.1
Disinfectants	0	0	0	0.0,0.0
Fungicides	0	0	0	0.0,0.0
Hydrocyanic acid and cyanides	0	0	0	0.0,0.0
Rodenticides	0	0	0	0.0,0.0

3.4. Discussion

Pesticides were the 8th most common exposure for children ≤ 5 years to U.S. poison centers (Mowry et al. 2015). Pesticides are associated with a variety of health effects, ranging from headaches, rashes, cancers, and developmental delays (Karr et al. 2007). It is vital that the impact of pesticide exposures in children is better understood. The study supports that pesticides are a significant exposure that resulted in 158 hospitalizations in children ≤ 19 years from 2004-2013 in Texas.

The present study found that for pesticide-related hospitalizations among children age ≤ 19 years, 80.38% were due to unintentional exposures, and 19.62% were due to intentional exposures. This differs from the data in American Association of Poison Control Centers' National Poison Data System, reporting that for all pesticide ingestions, 94% were unintentional and 6% were intentional (Roberts et al. 2012). Due to the fact there is no surveillance system that captures pesticide exposures, it is impossible to estimate the total burden of pesticide exposures in Texas or the U.S. However, globally in 2002, pesticide ingestion resulted in 186,000 deaths (WHO 2010).

EPA market estimates show the herbicides 2,4-dichlorophenoxyacetic acid (2,4-D), glyphosate, mecoprop (MCPP), pendimethalin, dicamba, trifluralin, pelarganoc acid; the organophosphates/carbamates malathion and carbaryl; and pyrethroids were the 10 most commonly used conventional pesticide active ingredients for 2006-2007 (Grube et al. 2011). In addition, a pesticide inventory conducted in Webb and Hidalgo County, Texas found the most commonly reported pesticide were pyrethroids (Ross et al. 2015). This study found the most common pesticide categories included organophosphates/carbamates, as well as other pesticides, that include herbicides and pyrethroids/pyrethrins based on the ICD-9-CM and E-Code classifications.

The study found pesticide-related hospitalizations due to both unintentional and intentional pesticide exposures decreased from 2004-2013. It is unclear whether this represents a trend that will continue, and if so, why this decrease has occurred.

In the present study, children aged 15 to 19 years had a higher prevalence of intentional pesticide exposures. For adolescents and young adults aged 15 to 24 years had a suicide rate of 11.6 per 100,000 in 2014 (American Foundation for Suicide Prevention [AFSP] 2016). Self-harm and suicide are serious public health concerns. Following cancer and heart disease, suicide accounts for more years of life lost than any other cause of death (AFSP 2016). Poisonings, including pesticides account for 15.9% of suicide deaths in 2014 (AFSP 2016). The present study found adolescents age 15 to 19 years were the most likely to be hospitalized due to intentional exposures. This age group is at increased risk of suicide nationally; thus, more research should address the use of intentional pesticide exposures.

The findings of this study are supported by existing literature (Badakhsh et al. 2010; Mehler et al. 2006). Previous literature found that for pesticide-related hospitalizations males had higher rates (Badakhsh et al. 2010; Mehler et al. 2006). Badakhsh and colleagues (2010) also found that pesticide-related hospitalizations decreased during their study period. However, both previous studies found that intentional pesticide-related hospitalizations accounted for over 25% of cases, whereas this present study found that intentional pesticide-related hospitalizations account for approximately 18% of cases (Badakhsh et al. 2010; Mehler et al. 2006). This could be due to differences in study population: this study focused on children ≤ 19 years old, and they focused on all cases (Badakhsh et al. 2010; Mehler et al. 2006). Next, Badakhsh and colleagues (2010) found for children ≤ 18 years there was an average of 12 hospitalizations per year. The present study found an average of 15.8 cases per year. Despite similar average numbers of pesticide-related hospitalizations, the studies found different rates for children which may be due to differences in the definition of children used in the studies, as well as population size differences between the states (Badakhsh et al. 2010; Mehler et al. 2006).

A limitation of this study is that hospitalization data only capture acute exposures and miss chronic exposures and long term consequences (Badakhsh et al. 2010). In addition, visits to urgent care, primary care physicians, and emergency rooms are not included in the dataset which misses cases that do not require hospitalization. Some pesticide-related hospitalization cases may have been missed by using the available ICD-9-CM codes and E-codes. Not all hospitalizations may have been reported depending on collection and billing cycles (Texas DSHS 2013a). Badakhsh and colleagues (2010) analyzed hospital discharge data compared to cases identified using a surveillance program and found that the hospital discharge data was missing 54 pesticide-related hospitalizations. Another limitation is potential misclassification of cases, because some of the pesticide-related categories can include substances other than pesticides. For example, formaldehyde is reported under E-code E861.4 (disinfectant), but formaldehyde has many uses, such as in building materials, household products, and pesticides (Pesticide Action Network [PAN] 2016). Another limitation of hospitalization data, is that many pesticides were classified as “other” due to the current codes. However, this will largely be solved by the implementation of ICD-10 codes in October 2015 which includes additional pesticide-related categories, including herbicides and halogenated insecticides (Centers for Medicare and Medicaid Services [CMS] 2016). Lastly, another limitation is the use of the APR-DRG for illness severity because this classification is dependent on the underlying problem which can be confounded by complicating or comorbid conditions. Illness severity is patient and disease-specific; thus, interpretation of illness severity should be conducted with caution (Averill et al. 2003a). Thus, a child with a pre-existing condition may not experience the same health effects that a healthy child would experience as a result of pesticide exposure.

Despite these limitations this study was able to characterize childhood pesticide-related hospitalizations in Texas from 2004-2013. To our knowledge, this study was one of the first to utilize hospitalization data to identify pesticide-related hospitalizations in children in Texas. In addition, the study utilized both ICD-9-CM and E-codes for the case definition which allowed for more potential cases to be identified. In addition, the study analyzed all pesticide-related codes for each case to report the most specific pesticide code which allowed for understanding of the most commonly reported pesticide categories along with the most common potential health effects. Next, this study only reports a snapshot of pesticide-exposures that resulted in hospitalizations in Texas; however, the findings from this study are consistent with other state level data. This suggests that similar patterns exist throughout the United States. Lastly, to account for the limited sample size and to capture other exposures, the researchers are analyzing poison control center data to describe exposures reported to poison centers; this dataset has approximately 61,000 exposures for children age ≤ 19 years from 2000-2013 in Texas (Section 4).

3.5. Conclusions

Limited information is available on the prevalence of childhood pesticide exposures in Texas and the U.S. as a whole. This study characterized childhood pesticide-related hospitalizations in Texas and found that the child's age was an important variable in determining risk of hospitalization due to both unintentional and intentional pesticide exposures. In addition, males had a higher prevalence of pesticide-related hospitalizations. This information gained from this study can be used to develop tailored interventions, for example, to address the use of pesticides for self-harm among adolescents. The present study supports the utilization of a surveillance program to address acute pesticide poisonings in children, such as the Pesticide Exposure Surveillance in Texas (PEST) program which requires known and suspected acute occupational pesticide poisonings to be reported (Texas DSHS 2014).

Through analysis of Texas hospitalization data, the burden of pesticide exposures in children in Texas and the United States can begin to be understood; however, additional studies utilizing other state or national data should be utilized to capture pesticide-related exposures throughout the United States (poison center data, mortality data, and cancer registries). Research is also needed to characterize risk factors for pesticide exposures, to guide the development of interventions.

4. PESTICIDE-RELATED POISON CENTER EXPOSURES IN CHILDREN IN TEXAS, 2000-2013

4.1. Introduction

Under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), pesticides include substances that prevent, destroy, repel, or mitigate pests; are used as a plant regulator, defoliant, or desiccant; or are used as a nitrogen stabilizer (U.S. EPA 2016b). Infants and children are more susceptible to the effects of pesticides compared to adults (NPIC 2015). Acute health effects of pesticide exposures include nausea, headaches, rashes, seizures, coma, and death. Chronic health effects of pesticide exposures include birth defects, cancer, asthma, and neurodevelopmental effects (Karr et al. 2007). A meta-analysis found childhood exposures to residential insecticides were associated with increased risk of childhood leukemia and lymphomas (Chen et al. 2015). Pooled analyses of 12 case-control studies found pesticide exposure was significantly associated with acute lymphoblastic leukemia (ALL) and acute myeloid leukemia (AML) in children (Bailey et al. 2015).

The 2014 Annual Report of the American Association of Poison Control Centers' National Poison Data System (AAPCC NPDS) found pesticides were the 9th most common substance category involved in human exposures (3.22% of all exposures) (Mowry et al. 2015). For children ≤ 5 years, pesticides were the 8th most common substance category involved in human exposures (3.27% of all exposures) (Mowry et al. 2015). This is an increase from 2009, when pesticides were the 10th most common substance involved in human exposures and 9th most common for children ≤ 5 years (Bronstein et al. 2010).

There is limited current information on the burden of childhood pesticide exposures. A few studies examined pesticide exposures in children approximately a decade ago by utilizing poison center data and other data (Belson et al. 2003; Spann et al. 2000; Sumner and Langley 2000). A 2012 literature review characterized pesticide exposures in children and associated health effects (Roberts et al. 2012). The study purpose is to characterize pesticide-related poison center exposures involving children age ≤ 19 years in Texas during 2000-2013 to understand the potential impact of pesticides.

4.2. Materials and Methods

4.2.1. Data Collection

The study used data from the Texas Poison Center Network (TPCN) from 2000-2013 through a data agreement with the Texas Department of State Health Services (DSHS). The TPCN consists of six poison centers that serve Texas (TPCN n.d.). An electronic database, Toxicall, is used to collect data which ensures data consistency (Texas DSHS 2012). As per the AAPCC, exposure refers to someone who has had contact with the substance, but not all exposures are poisonings (Mowry et al. 2015). Information is self-reported (Mowry et al. 2015). Additional exposures may not be reported to poison centers and the data does not represent the complete incidence of exposures (Mowry et al. 2015). Cases were defined as all calls pertaining to children aged ≤ 19 years during 2000-2013 in Texas with a pesticide reported as an exposure that was determined to be unintentional or intentional. Intent was defined as unintentional or intentional based on the exposure reason. Unintentional exposures included codes for general, environmental, occupational, therapeutic error, misuse, bite/sting, food poisoning, adverse reactions, and unknown-unintentional. Intentional exposures included codes for misuse, abuse, and unknown-intentional. There were 224 calls that were excluded due to undefined intent (e.g. other or unknown). Pesticide-related poison center exposures were excluded for those aged ≥ 20 years and those with an unknown adult age (n=34,240). Poisindex software assist poison center staff code calls; the software contains information on 400,000 chemical and household products that have a unique product code and a generic code (AAPCC 2015). Pesticide-related calls were pulled using pesticide-related generic codes. Cases are referred to as pesticide-related poison center exposures. Variables included were intent (unintentional or intentional), age, gender, medical outcome, management site, exposure route, and pesticide classification. Patient age categories were children ≤ 5 years, children 6-12 years, and children 13-19 years. Gender was classified as female, male, and unknown.

The medical outcome was assigned by the poison center staff based on observed or anticipated health effects. Medical outcome is classified into the following categories: no effect (no symptoms due to exposure), minor effect (some minimally troublesome symptoms), moderate effect (more pronounced, prolonged symptoms), major effect (symptoms that are life-threatening or cause significant disability), and death. Portions of exposures are not followed to a final medical outcome because of the inability to obtain subsequent information; the outcome is classified based on the expected outcome by poison center staff. Expected outcome categories include: not followed but judged as nontoxic exposure (symptoms not expected), not followed but minimal symptoms possible (no more than minor symptoms possible), unable to follow but judged as a potentially toxic exposure. The definitions for medical outcome are provided by the AAPCC which defines outcome based on symptoms (Mowry et al. 2015).

Management site defines where the exposure was managed (e.g. on site, being treated in Health Care Facility (HCF), referred to a HCF by a poison center, other, and unknown). Next, exposure routes were classified as ingestion, inhalation, aspiration, ocular, dermal, bite, parenteral, otic, rectal, vaginal, other, and unknown. There were more exposure routes reported than exposures because more than one exposure route could be reported for each exposure.

Pesticide categories were defined based on the provided substance description. There were more substances reported than exposures due to the fact exposures could report multiple substances. Pesticide categories included fumigants; fungicides; herbicides; mixtures of insecticides; natural pesticides; not a pesticide; not a chemical pesticide; organochlorines; organophosphates/carbamates; other and unspecified insecticides; pyrethrin/pyrethroid; rodenticides; synergists only reported; and unable to classify. Pesticide categories were selected based on existing ICD-9-CM and E-code pesticide-related codes in order to use a standard classification system. Categories for pyrethrins/pyrethroids, natural pesticides (e.g. citronella oil), not a pesticide (e.g. Diurex), not a chemical pesticide (e.g. glue trap), synergists only reported, and unable to classify were created to better classify the substances reported. There were 16 pesticide categories used to classify pesticide-related poison center exposures.

Seasons were defined by month of call: spring (March-May), summer (June-August), fall (September-November), and winter (December-February). Population data for children aged 19 years and under, by gender and age groups, was obtained from 2010 decennial census (USCB 2016).

4.2.2. Data Analysis

This research was deemed exempt by the Texas A&M Institutional Review Board (IRB) (Study #2015-0563M) and by the Texas Department of State Health Services (DSHS) IRB (IRB #14-064). Microsoft Access/Excel and STATA 14 were used for data management and analysis (Microsoft Corporation, Redmond, WA; StataCorp LP, College Station, TX). The frequency, prevalence, and 95% confidence intervals (CIs) of pesticide-related poison center exposures were calculated for all of Texas by intent, as well as for medical outcomes by intent. Age-specific and sex-specific prevalence were calculated. Next, the frequency of exposure route, pesticide category, year of exposure, and seasons of exposures was calculated.

4.3. Results

4.3.1. Pesticide-Related Texas Poison Center Exposures

During 2000-2013 there were a total of 95,611 pesticide-related poison center exposures among all ages. Of those there were 61,147 pesticide-related poison center exposures among children age ≤ 19 years reported to the TPCN. Figure 2 shows the number of these exposures by year and intent. The annual average number of pesticide-related poison center exposures was 4,367 with a range of 3,253 to 5,300. For unintentional pesticide-related poison center exposures, there was an average of 4,323 exposures annually with a range of 3,214 to 5,270; whereas the annual average number of intentional pesticide-related poison center exposures was 44 with a range of 30 to 58. Figure 3 shows the number of exposures by season and intent. For unintentional pesticide-related poison center exposures, 32.10% occurred in the summer and 25.56% occurred in the spring; whereas for intentional pesticide-related poison center exposures, 30.65% occurred in the spring and 28.87% occurred in the summer. Overall 32.08% and 25.62% of calls occurred in the summer and spring, respectively.

Figure 2 Annual Number of Pesticide-Related Poison Center Exposures for Children age ≤ 19 years in Texas, 2000-2013

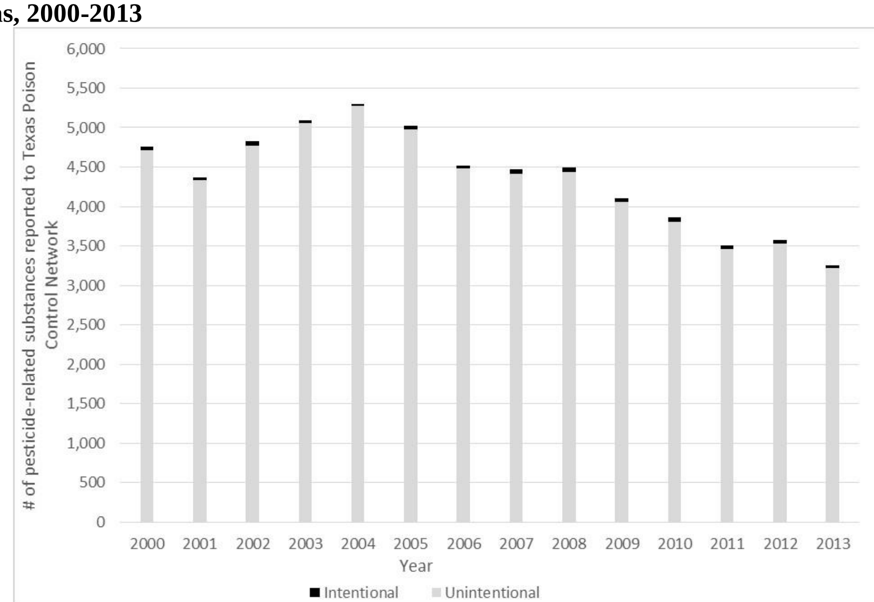


Figure 3 Seasonal Frequency of Pesticide-Related Poison Center Exposures by Intent for Children age ≤ 19 years in Texas, 2000-2013

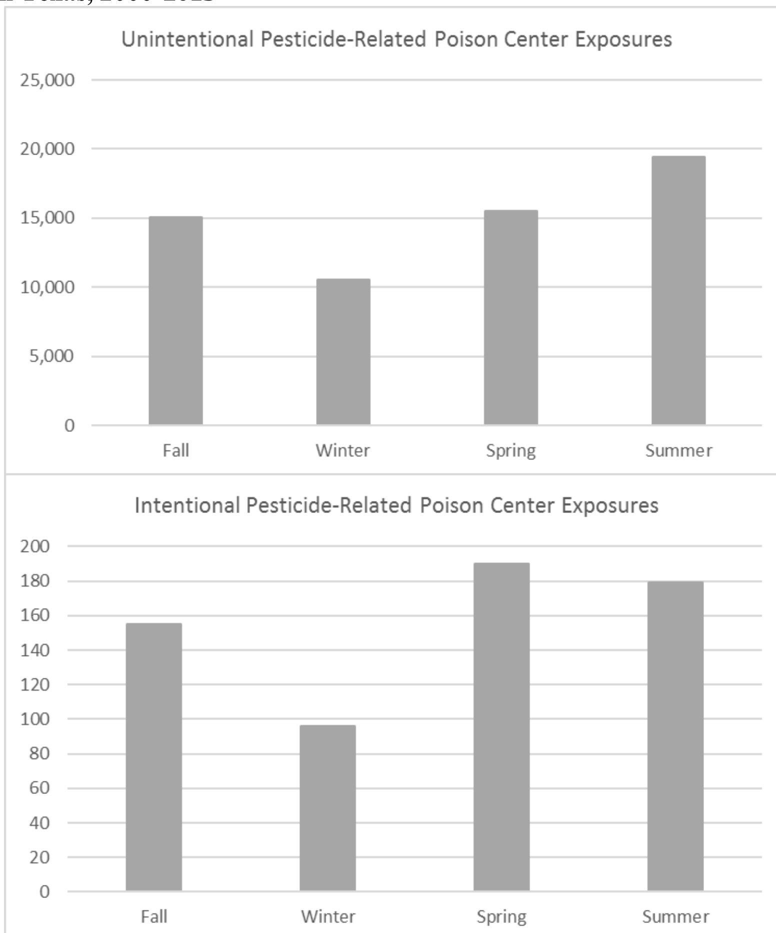


Table 7 shows the frequency and prevalence of pesticide-related poison center exposures by demographics and intent. The prevalence of pesticide-related poison center exposures for Texas was 802.27 per 100,000 population (95% CI 795.94, 808.61). The gender-specific prevalence was different with an estimated 864.24 per 100,000 male population (95% CI 855.05, 873.42) versus 732.31 per 100,000 female population (95% CI 723.65, 740.97). Age-specific prevalence for children aged ≤ 5 years was the highest (2315.06 per 100,000 population; 95% CI 2,295.69, 2,334.42).

Table 7 Pesticide-Related Poison Center Exposure Frequency and Prevalence for Children age ≤ 19 years in Texas, 2000-2013[a]

	# of Exposures	% of Exposures	Prevalence per 100,000	95% CI[b]
Pesticide-Related Poison Center Exposures (N=61,147)				
Texas	61,147	100.00	802.27	795.94,808.61
Males[c]	33,701	55.11	864.24	855.05,873.42
Females[c]	27,258	44.58	732.31	723.65,740.97
<=5 years old[c]	53,615	87.68	2,315.06	2295.69,2334.42
6 to 12 years old[c]	4,425	7.24	165.15	160.29,170.01
13 to 19 years old[c]	2,700	4.42	102.80	98.92,106.68
Unintentional Pesticide-Related Poison Center Exposures (N=60,527)				
Texas	60,527	100.00	794.14	787.84,800.44
Males[c]	33,356	55.11	855.39	846.25,864.53
Females[c]	26,989	44.59	725.08	716.46,733.70
<=5 years old[c]	53,514	88.41	2,310.69	2,291.34, 2,330.04
6 to 12 years old[c]	4,283	7.08	159.85	155.07,164.64
13 to 19 years old[c]	2,337	3.86	88.98	85.37,92.59
Intentional Pesticide-Related Poison Center Exposures (N=620)				
Texas	620	100.00	8.13	7.49, 8.77
Males[c]	345	55.65	8.85	7.91, 9.78
Females[c]	269	43.39	7.23	6.36,8.09
<=5 years old[c]	101	16.29	4.36	3.51, 5.21
6 to 12 years old[c]	142	22.90	5.30	4.43, 6.17
13 to 19 years old[c]	363	58.55	13.82	12.40, 15.24

[a] There were 188 exposures with unknown gender and 407 with unknown age.
[b] 95% Confidence Interval
[c] Age-specific and Sex-specific Prevalence

Of the pesticide-related poison center exposures, 60,527 were due to unintentional exposures with a prevalence of 794.14 per 100,000 population (95% CI 787.84, 800.44). The gender-specific prevalence differed with 855.39 per 100,000 male population (95% CI 846.25, 864.53) and 725.08 per 100,000 female population (95% CI 716.46, 733.70). Children aged ≤ 5 years had the highest number of unintentional pesticide-related poison center exposures with a prevalence of 2,310.69 per 100,000 population in this age group (95% CI 2,291.34, 2,330.04). The remaining 620 pesticide-related poison center exposures were due to intentional exposures for the time period which resulted in a prevalence of 8.13 per 100,000 population (95% 7.49, 8.77). The gender-specific prevalence was 8.85 per 100,000 males (95% CI 7.91, 9.78) and 7.23 per 100,000 females (95% CI 6.36, 8.09). Children aged 13 to 19 years had the highest number of intentional pesticide-related poison center exposures with a prevalence of 13.82 per 100,000 in this age group (95% CI 12.40, 15.24).

Table 8 presents pesticide-related poison center exposure frequency and prevalence by medical outcome. The majority of exposures were classified as having no effect (30.24%) or not followed, but with minimal clinical effects possible (42.74%). The prevalence for these categories was 242.60 per 100,000 population (95% CI 239.10, 246.09) and 342.90 per 100,000 population (95% CI 338.75, 347.05), respectively. This was similar for unintentional exposures. For intentional exposures, the most common medical outcomes were no effect; minor effect; not followed, but with minimal clinical effects possible; and unable to follow, but judged as a potentially toxic exposure.

Management site was analyzed to understand how many exposures were referred to or treated at HCFs (Figure 4). Of all pesticide-related poison center exposures, a majority (81.24%) were managed on site which means they were not referred or treated at a HCF. For all exposures, 15.27% were in route to a HCF when the poison center was called and 2.95% were referred to a HCF by the poison center. These percentages were similar when stratified for unintentional exposures. For intentional pesticide-related poison center exposures, 40.81% were managed on site, 45.00% were in route to HCF when the poison center was called, and 12.42% were referred to a HCF by the poison center.

Next, pesticide-related poison exposures were analyzed to determine common routes of exposure (Table 9). Common exposure routes were ingestion (80.83%) and dermal (17.21%). This was similar for unintentional exposures. Categories representing a majority of exposures for intentional exposures were ingestion (70.16%), dermal (23.39%), and inhalation (10.97%).

Lastly, pesticide-related poison center exposures were analyzed to determine pesticide classifications (Table 10). Categories that represented a majority of all exposures were other and unspecified insecticides (18.14%); pyrethrins/pyrethroids (20.69%); and rodenticides (30.02%). In addition, 10.80% of exposures were unable to be classified into a pesticide classification. This was similar for unintentional exposures. The most common pesticide categories for intentional exposures were pyrethrins/pyrethroids (30.65%), rodenticides (22.90%), and other and unspecified insecticides (13.71%).

Table 8 Pesticide-Related Poison Center Exposure Frequency and Prevalence in Texas by Medical Outcome for Children age ≤ 19 years, 2000-2013

Medical Outcome	# of Exposures	% of Exposures	Prevalence per 100,000	95% CI[a]
Pesticide-Related Poison Center Exposures (N=61,147)				
No Effect	18,490	30.24	242.60	239.10,246.09
Minor Effect	5,431	8.88	71.26	69.36,73.15
Moderate Effect	643	1.05	8.44	7.78,9.09
Major Effect	54	0.09	0.71	0.52,0.90
Death	2	0.00	0.03	-0.01,0.06
Not followed, judged as nontoxic	7,450	12.18	97.75	95.53,99.97
Not followed, minimal clinical effects possible	26,135	42.74	342.90	338.75,347.05
Unable to follow, judged as a potentially toxic exposure	1,322	2.16	17.35	16.41,18.28
Unrelated, exposure was probably not responsible for the effect(s)	1,620	2.65	21.26	20.22,22.29
Unintentional Pesticide-Related Poison Center Exposures (N=60,527)				
No Effect	18,305	30.24	240.17	236.69,243.64
Minor Effect	5,318	8.79	69.77	67.90,71.65
Moderate Effect	613	1.01	8.04	7.41,8.68
Major Effect	42	0.07	0.55	0.38,0.72
Death	2	0.00	0.03	-0.01,0.06
Not followed, judged as nontoxic	7,429	12.27	97.47	95.26,99.69
Not followed, minimal clinical effects possible	25,967	42.90	340.70	336.56,344.83
Unable to follow, judged as a potentially toxic exposure	1,250	2.07	16.40	15.49,17.31
Unrelated, exposure was probably not responsible for the effect(s)	1,601	2.65	21.01	19.98,22.03

Table 8 Continued

Medical Outcome	# of Exposures	% of Exposures	Prevalence per 100,000	95% CI[a]
Intentional Pesticide-Related Poison Center Exposures (N=620)[b]				
No Effect	185	28.91	2.43	2.08, 2.78
Minor Effect	113	17.66	1.48	1.21, 1.76
Moderate Effect	30	4.69	0.39	0.25, 0.53
Major Effect	12	1.88	0.16	0.07, 0.25
Not followed, judged as nontoxic	21	3.28	0.28	0.26, 0.39
Not followed, minimal clinical effects possible	167	26.09	2.19	1.86, 2.52
Unable to follow, judged as a potentially toxic exposure	72	11.25	0.94	0.73, 1.16
Unrelated, exposure was probably not responsible for the effect(s)	19	2.97	0.25	0.14, 0.36

[a] 95% Confidence Interval

[b] Death was not a reported outcome for Intentional Pesticide-Related Poison Center Exposures

Figure 4 Management Site for Pesticide-Related Poison Center Exposures by Intent for Children age ≤ 19 years in Texas, 2000-2013

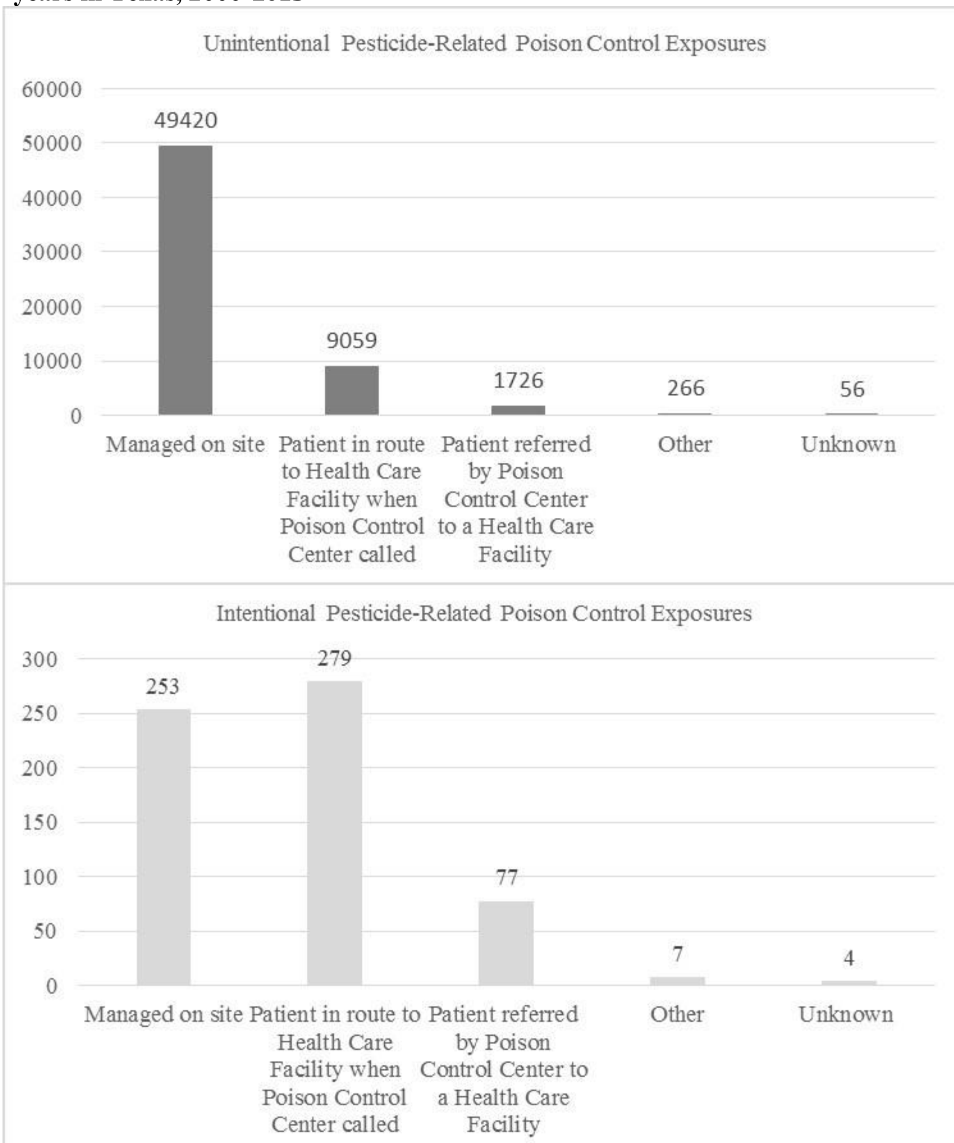


Table 9 Exposure Route of Pesticide-Related Poison Center Exposures in Children age ≤ 19 years, 2000-2013[a]

Exposure Route	# by this Route	% of Responses (N=68 061)	% of Exposures (N=61,147)	# of Unintentional by this Route	% of Unintentional Responses (N=67,385)	% of Unintentional Exposures (N=60,527)	# of Intentional by this Route	% of Intentional Exposures (N=676)	% of Intentional Exposures (N=620)
Ingestion	49,428	72.62	80.83	48,993	72.71	80.94	435	64.35	70.16
Inhalation	2,445	3.59	4	2,377	3.53	3.93	68	10.06	10.97
Aspiration	8	0.01	0.01	8	0.01	0.01	0	0	0
Ocular	5,400	7.93	8.83	5,386	7.99	8.9	14	2.07	2.26
Dermal	10,523	15.46	17.21	10,378	15.4	17.15	145	21.45	23.39
Bite	16	0.02	0.03	16	0.02	0.03	0	0	0
Parenteral	6	0.01	0.01	3	0	0	3	0.44	0.48
Otic	41	0.06	0.07	37	0.05	0.06	4	0.59	0.65
Rectal	2	0	0	2	0	0	0	0	0
Vaginal	4	0.01	0.01	4	0.01	0.01	0	0	0
Other	52	0.08	0.09	51	0.08	0.08	1	0.15	0.16
Unknown	136	0.2	0.22	130	0.19	0.21	6	0.89	0.97

Table 10 Pesticide-Related Poison Center Exposure Frequency and Prevalence in Texas by Pesticide Category, 2000-2013[a]

Pesticide Category	# of Exposures	% of Responses (61,777)	% of Exposures (N=61,147)	# of Unintentional Exposures	% of Unintentional Responses (N=61,136)	% of Unintentional Exposures (N=60,527)	# of Intentional Exposures	% of Intentional Responses (N=641)	% of Intentional Exposures (N=620)
Fumigants	28	0.05	0.05	28	0.05	0.05	0	0.00	0.00
Fungicides	264	0.43	0.43	262	0.43	0.43	2	0.31	0.32
Herbicides	1,957	3.17	3.20	1,933	3.16	3.19	24	3.74	3.87
Mixtures of Insecticides	2,487	403	4.07	2,467	4.04	4.08	20	3.11	3.23
Natural Pesticides	3,550	5.75	5.81	3,521	5.76	5.82	29	4.53	4.68
Not a Pesticide	100	0.16	0.16	99	0.16	0.16	1	0.16	0.16
Not a Chemical Pesticide	579	0.94	0.95	579	0.95	0.96	0	0.00	0.00
Organochlorines	736	1.19	1.20	708	1.16	1.17	28	4.38	4.52
OPs/ Carbamates	3,267	5.29	5.34	3,209	5.25	5.30	58	9.06	9.35
Other and Unspecified insecticides	11,091	17.95	18.14	11,006	18.00	18.18	85	13.28	13.71
Pyrethrin/ Pyrethroid	12,654	20.48	20.69	12,464	20.39	20.59	190	29.69	30.65
Rodenticides	18,355	29.71	30.02	18,213	29.79	30.09	142	22.19	22.90
Synergists Only Reported	106	0.17	0.17	105	0.17	0.17	1	0.16	0.16
Unable to classify	6,603	10.69	10.80	6,542	10.70	10.81	61	9.53	9.84

[a] Sum of percentages of exposures are greater than N for all categories because some exposures reported more than one route of exposure

4.4. Discussion

This study found an average of 4,367 pesticide-related poison center exposures reported to annually from 2000 to 2013 with a total of 61,147 pesticide-related exposures for children ≤ 19 being reported. Of these, males and children age ≤ 5 years were most impacted. The study found children age ≤ 5 years were most affected by unintentional exposures, whereas children aged 13 to 19 years old were most impacted by intentional exposures.

The present study found that overall pesticide-related poison center exposures reported pertaining to children aged ≤ 19 years decreased over the time period for both unintentional and intentional exposures. Based on the analysis, it is unclear if this is a trend that will continue, and if so, why this decrease occurred. In addition, the present study found that a majority of calls occurred in the summer and spring, respectively. Existing literature has found that urinary biomarkers of pesticides for children exhibited within-person variability over four seasons (Attfield et al. 2013). Intraclass correlation coefficients (ICCs) were higher in the fall- spring for organophosphates which may reflect seasonal variation in dietary sources; however, ICCs were higher in the summer for pyrethroids which may reflect increased pesticide use (Attfield et al. 2013). The present study also found that more reports pertained to males than females (55.11% were males compared to 44.58% females). A 2008 World Health Organization (WHO) report on child injury prevention found that boys had higher rates than girls for poisonings throughout the world except for in countries in the Western Pacific region (Peden et al. 2008). In addition, the study found that for unintentional pesticide exposures children aged ≤ 5 years were most likely to be exposed; whereas for intentional pesticide exposures children aged 13 to 19 years old were most likely to be exposed. This is supported by existing literature. For example, the World Health Organization (WHO) found that young children are susceptible to unintentional exposures, whereas adolescents are susceptible to poisoning due to intentional exposures (Peden et al. 2008). Another WHO report found that younger children are susceptible to poisonings because of their inquisitiveness and mouthing behavior; whereas adolescents are aware of the risks of poisonings, but are more likely to intentionally misuse poisons (WHO 2008). In addition, the report found that males had higher rates of poisonings which is believed to be a result of differences in socialization (WHO 2008).

Of all the exposures 42.42% were deemed to have no effect or were judged as nontoxic, whereas 52.67% of exposures were deemed to result in minimal clinical effects, minor effects, or moderate effects. The medical outcome is supported by management site, which showed 81.24% of exposures were managed on site (not in a HCF), while 18.22% of exposures were treated at or referred to a HCF. Roberts and colleagues (2012) report that poison centers are reporting lower rates of more severe pesticide exposures, but the number of reported pesticide exposures remain similar annually. This finding regarding lower rates of severe exposures supports the present study's finding that fewer exposures required treatment at a HCF.

The 2014 AAPCC NPDS report found that the most common routes of exposure were ingestion (83.74%), dermal (7.01%), inhalation/nasal (6.13%), and ocular routes (4.25%) for all human exposure cases (Mowry et al. 2015). This present study found similar exposure routes; however, overall there were a higher percentage of dermal (17.21%) and ocular (8.83%) exposure routes, with a lower percentage of inhalation (4.00%) and ingestion (80.83%). This was similar for unintentional exposures. For intentional exposures, the most common exposure routes reported were ingestion (70.16%), dermal (23.39%), inhalation (10.97%), and ocular (2.26%). Exposure via dermal and inhalation routes was higher among intentional exposures than among unintentional exposures or in the 2014 AAPCC NPDS report (Mowry et al. 2015).

The top 10 most commonly used conventional pesticide active ingredients from the 2006-2007 Environmental Protection Agency (EPA) market estimates were the herbicides 2,4-dichlorophenoxyacetic acid (2,4-D), glyphosate, mecoprop (MCPP), pendimethalin, dicamba, trifluralin, pelarganoc acid; the organophosphates/carbamates malathion and carbaryl; and pyrethroids (Grube et al. 2011). A household pesticide inventory in South Texas found the most commonly reported pesticide class was pyrethroids (Ross et al. 2015). The present study found the most common pesticide categories were pyrethrins/pyrethroids, rodenticides, and other and unspecified insecticides.

A limitation of using poison center data is that providing data about exposures is voluntary, which means callers can refuse to provide information. Also, the information is self-reported typically by a child’s parent or guardian, which may result in missing data or reporting bias that may lead to underestimates of exposure. In addition, the dataset only captures information about reported exposures and should not be assumed to represent all exposures to a substance (Mowry et al. 2015). This study only captures reported exposures and is a baseline for the minimum number of exposures, but the true number of exposures is unknown and unattainable. A second limitation is that poison center data capture acute exposures, which misses chronic exposures and long-term consequences. A third potential limitation is poisons that are not pesticides may be classified as a pesticide or vice-versa, which results in potential misclassification of poison center exposures. This study found 0.16% of the pesticide-related poison center exposures were misclassified as a pesticide. An example is Diurex which is a diuretic. Another limitation is that multiple exposures could be for the same child. Despite these limitations this study was able to characterize childhood pesticide-related poison center exposures in Texas from 2000-2013. Children ≤ 19 years represented 64.19% of all pesticide exposures reported to the TPCN from 2000-2013. In addition, this is one of the first studies to classify exposures into pesticide categories based on substance description which allows for a better understanding of the type of pesticides children are exposed to, as well as potential health effects due to existing knowledge of pesticide categories. The study also covered 14 years of data which allowed for understanding of potential temporal trends. This study also utilized date information to understand seasonal variations of childhood pesticide exposures.

4.5. Conclusion

Childhood pesticide exposures are common and are associated with a multitude of health effects. At this time there is limited literature on the prevalence of childhood pesticide exposures in Texas and the United States as a whole. Through analyzing poison center exposures, this study was able to begin to fill gaps in understanding the impact of pesticides on children. The information gained from this study can be utilized for future research and interventions. For example, through understanding who is most at risk of unintentional and intentional exposure, future interventions can be designed to target each age group appropriately as well as educate clinicians and public health practitioners. In addition, the information from this study can be utilized to inform parents and child care providers on the potential risks of pesticide exposures.

This study utilizes available poison center data which provides a snapshot into the burden of childhood pesticide exposures in Texas. Based on the findings of this study, further monitoring of childhood pesticide exposures would be useful. Future research should focus on understanding the overall burden of childhood pesticide exposures through other available data (e.g. mortality, emergency room, hospitalization). Through utilizing multiple datasets, the burden of childhood pesticide exposures can be understood. In addition, future research should go beyond a cross-sectional analysis and collect or involve longitudinal data. Additional research is needed to understand the risk factors for childhood pesticide exposures, which can guide future tailored prevention methods and policies. For example, Texas has many rural and agriculturally intensive areas which may influence pesticide exposures; thus, future research could include spatial clustering and regression analyses for better understanding of pesticide exposures.

5. CHARACTERIZING CHILDHOOD PESTICIDE-RELATED EXPOSURES IN TEXAS THROUGH SECONDARY DATA: COMPARISON OF POISON CENTER AND HOSPITALIZATION INPATIENT DATA, 2004-2013

5.1. Introduction

In 2014, pesticides were the 9th most commonly reported substance category to national poison centers for all human exposures and the 8th most commonly reported substance category for children ≤ 5 years (Mowry et al. 2015). Symptoms of pesticide exposures range from skin irritation to coma and death in extreme cases (Lorenz 2009). Chronic health effects of pesticide exposures in children include cancer, neurodevelopmental issues, asthma, and endocrine-mimicking effects (Roberts et al. 2012). Symptoms of pesticide exposures vary due to a multitude of factors, such as dose, exposure route, pesticide class, and individual susceptibility (Lorenz 2009). Infants and children are particularly susceptible to the effects of pesticides compared to adults. This is due to multiple factors, including that children are developing, they breathe more times per minute, they have more skin surface relative to body weight, and they exhibit behaviors that increase exposure risk (e.g., playing close to or on the ground and putting objects in their mouths) (NPIC 2015).

Despite the known health effects of pesticides in children, and the fact pesticides are a commonly reported childhood exposure, there is limited current information on the burden of childhood pesticide exposures in the United States (U.S.). There are a few studies that have examined pesticide exposures through utilizing poison center data (Belson et al. 2003; Forrester 2013; Spann et al. 2000), hospitalization data (Badakhsh et al. 2010), or multiple secondary data sets (Mehler et al. 2006; Sumner and Langley 2000), but few were published within the last five years. A recent literature review found that there is no currently reliable single data source that addresses the burden of pesticide exposure and associated health effects in children (Roberts et al. 2012). Roberts and colleagues (2012) suggest the utilization of secondary datasets, such as poison center data, to capture information on acute pesticide exposures and potential trends (Roberts et al. 2012).

The objective of this study is to compare pesticide-related hospitalizations and pesticide-related poison center exposures in children ≤ 19 years in Texas. The study compared primary findings from the two datasets (hospitalization and poison center), as well as discussed the strengths and weaknesses of both. Through comparison of both pesticide-related exposure datasets, the burden of pesticide exposures can be characterized for children ≤ 19 years in Texas and the benefit to utilizing multiple datasets can be assessed. To address pesticide exposures in children, separate investigations were done through descriptive analyses and by estimating prevalence for pesticide-related hospitalizations and pesticide-related poison center exposures in children ≤ 19 years in Texas (Sections 3 and 4).

5.2. Methods

5.2.1. Data Collection

Cases were children ≤19 years with pesticide exposures that were included in at least one of two datasets during 2004-2013. First, the Texas Health Care Information Collection (THCIC) Texas Inpatient Public Use Data File (PUDF) contains information on hospital discharges in Texas with information on age, sex, race, ethnicity, length of stay, admission status, severity, diagnoses, cost of hospitalization, and payer information (Texas DSHS 2013a). For the purposes of this study, only age, sex, year of hospitalization, and diagnosis codes were used to make comparisons between hospitalization data and poison center data. All hospital discharges are included in THCIC except for exempt hospitals (those in counties with less than 35,0000 people, those with fewer than 100 licensed hospital beds, and those areas not urbanized by the United States Bureau of the Census (USCB) (Texas DSHS 2013a). Cases were defined using pesticide-related International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) codes and external causes of injury (E-codes) defined by the National Institute for Occupational Safety and Health (NIOSH) Pesticide Program and previous literature (see Table 11) (Badakhsh et al. 2010; Mehler et al. 2001; NIOSH et al. 2005). Cases were also stratified by intent (i.e., unintentional or intentional exposure). Unintentional pesticide-related exposures that resulted in hospitalizations included ICD-9-CM codes 989.0-989.4 and E-Codes E861.4, E.863.0-E863.9 (Badakhsh et al. 2010; Mehler et al. 2001; NIOSH et al. 2005). Intentional pesticide-related hospitalizations included E-code 950.6 (suicide or self-inflicted poisoning with agricultural and horticultural chemicals) or records with a non-pesticide suicide or self-inflicted harm code (E-950.0-950.5; 950.7-950.9) as well as a pesticide-related ICD-9-CM code (Badakhsh et al. 2010; Mehler et al. 2001; NIOSH et al. 2005). For example, if a record had E-Code 950.5 (suicide and self-inflicted poisoning by unspecified drug or medicinal substance) and ICD-9-CM code 989.3 (toxic effect of organophosphates or carbamates), this was classified as an intentional pesticide-related hospitalization.

Table 11 ICD-9-CM and E-codes for Pesticide-Related Hospitalizations for Children age ≤ 19 years in Texas, 2004-2013

Code	Code Definition
ICD-9-CM codes	
989.0	Toxic Effect of Hydrocyanic Acid and Cyanides
989.1	Toxic Effect of Strychnine and Salts
989.2	Toxic Effect of Chlorinated Hydrocarbons
989.3	Toxic Effect of Organophosphate and Carbamate
989.4	Toxic Effect of Other Pesticides Not Elsewhere Classified
E-codes	
E861.4	Accidental Poisonings by Disinfectants
E863.0	Accidental Poisoning by Insecticides of Organochlorine Compounds
E863.1	Accidental Poisoning by Insecticides of Organophosphorus Compounds
E863.2	Accidental Poisoning by Carbamates
E863.3	Accidental Poisoning by Mixtures of Insecticides
E863.4	Accidental Poisoning by Other and Unspecified Insecticides
E863.5	Accidental Poisoning by Herbicides
E863.6	Accidental Poisoning by Fungicides
E863.7	Accidental Poisoning by Rodenticides
E863.8	Accidental Poisoning by Fumigants
E863.9	Accidental Poisoning by Other and Unspecified Agricultural and Horticultural Chemical and Pharmaceutical Preparations Other Than Plant Foods and Fertilizers
E980.7	Poisoning by Agricultural and Horticultural Chemical and Pharmaceutical Preparations Other than Plant Foods and Fertilizers Undetermined Whether Accidentally or Purposely Inflicted
E950.6	Suicide and Self-Inflicted Poisoning by Agricultural and Horticultural Chemical and Pharmaceutical Preparations Other than Plant Foods and Fertilizers
E950.0-E950.5; E950.7-E950.9	Suicide and Self-Inflicted poisoning with a pesticide-related ICD-9-CM code

Second, the Texas Poison Center Network (TPCN) assists in the management of potentially adverse exposures to a variety of substances, including pesticides. It consists of six poison centers that together service the entire state. They use a common electronic database to collect information on all calls in a consistent manner. Pesticide-related poison center exposure data include information on intent, patient age and sex, medical outcome, management site, exposure route, and pesticide classification. For the purposes of this study, only age, sex, year of exposure, and intent were used to make comparisons between hospitalization data and poison center data. Cases were defined as all exposures for children age ≤ 19 years during 2004-2013 in Texas with a pesticide reported as an exposure, as well as exposure reason being classified as unintentional (e.g. unintentional and adverse reactions) or intentional. Exposures coded as other or unknown exposure reason were excluded from the analysis. This was done through a Poisindex code created by Micromedex which was used to document the substances involved in the exposures (AAPCC 2015). The system contains information on over 400,000 chemical and household products that have been assigned a unique product code. Poisindex codes for related substances are grouped into a common generic code (AAPCC 2015).

For each dataset, the following variables were identified: year, patient age and sex, and intent (unintentional, intentional). Available age categories varied between the two datasets, making it infeasible to use identical age categories. However, categories were created to represent young children, school aged children, and adolescents, and these are defined for each dataset. Pesticide-related hospitalization age categories merged existing categories into children ≤4 years, children 5 to 14 years, and children 15 to 19 years (Texas DSHS 2013a), to correspond to the groups young children, school aged children, and adolescents, respectively. Pesticide-related poison center exposure age categories were defined using AAPCC groupings, including children ≤5 years, children 6 to 12 years, and children 13 to 19 years, to correspond to the groups young children, school aged children, and adolescents, respectively. Both datasets allowed for a common overall definition that included all children ≤19 years. Population data for children age ≤ 19 years was obtained from the USCB using 2010 decennial data. Annual population data for children ≤ 19 years was obtained from the Texas Department of State Health Services (DSHS) using census population and intercensal estimates (Texas DSHS 2015c).

5.2.2. Data Analysis

The frequency of pesticide-related hospitalizations and pesticide-related poison center exposures was calculated by sex, age, and year. Cases where the value for a particular variable was unknown were excluded from the analysis of that variable. Frequencies and prevalence of pesticide-related hospitalizations and poison center exposures by sex, age, and year were compared to identify similarities and differences in patterns between the datasets. Next, correlation was calculated to determine if the two datasets were associated for number of pesticide-related hospitalizations and poison center exposures by year.

This research was deemed exempt by the Texas A&M Institutional Review Board (IRB) (Study # 2015-0563M) and the Texas DSHS IRB (IRB #14-064) for the poison center data. Microsoft Access and Excel 2013 were used for data management and analysis (Microsoft Corporation, Redmond, WA).

5.3. Results

Table 12 shows the frequency and percentage of pesticide-related hospitalizations and pesticide-related poison center exposures, by patient sex and age.

For pesticide-related hospitalizations and poison center exposures males had a higher prevalence compared to females. Males had a higher prevalence of pesticide-related hospitalizations and poison center exposures for both unintentional and intentional exposures.

Next, for all pesticide-related hospitalizations, children ≤ 4 years had a higher prevalence of hospitalizations compared to other age groups (see Table 12). This was also true for unintentional pesticide-related hospitalizations. However, for intentional pesticide-related hospitalizations children aged 15 to 19 years had a higher prevalence of hospitalizations. For pesticide-related poison center exposures, children ≤ 5 years had a higher prevalence compared to other age groups. This was also true for unintentional pesticide-related poison center exposures. For intentional pesticide-related poison center exposures children aged 13 to 19 years had a higher prevalence compared to other age groups.

Over the time period, both pesticide-related hospitalizations and poison center exposures decreased. Table 13 shows the frequency and percentage of pesticide-related hospitalizations and poison center exposures by year. There was an average of 15.8 pesticide-related hospitalizations annually with a range from 8 to 23, whereas the average for pesticide-related poison center exposures was 4,210 annually with a range of 3,253 to 5,300. The highest number of hospitalizations was 23 in 2010; whereas, the highest number of pesticide-related poison center exposures was 5,300 in 2004. For unintentional exposures, there was an average of 12.7 pesticide-related hospitalizations annually with a range of 7 to 18; for pesticide-related poison center exposures there was

Table 12 Frequency and Prevalence of Pesticide-Related Hospitalizations and Poison Center Exposures in Children ≤19 years by Sex and Age, 2004-2013

		Hospitalizations				Poison Center Exposures[a]			
	Population Size[b]	Number of Cases	Percent of Cases	Prevalence per 100,000	95% CI	Number of Cases	Percent of Cases	Prevalence per 100,000	95% CI
All Hospitalizations/Exposures									
Males	3,899,515	104	65.82	2.67	2.15,3.18	23,396	55.57	599.97	592.31,607.64
Females	3,722,199	54	34.18	1.45	1.06,1.84	18,566	44.10	498.79	491.63,505.95
0 to 4 years	1,928,473	103	65.19	5.34	4.31,6.37				
5 to 14 years	3,810,117	11	6.96	0.29	0.12,0.46				
15 to 19 years	1,883,124	44	27.85	2.34	1.65,3.03				
0 to 5 years	2,315,927					36,699	87.17	1,584.64	1,568.55, 1,600.72
6 to 12 years	2,679,342					3,112	7.39	116.15	112.07,120.23
13 to 19 years	2,626,445					1,968	4.67	74.93	71.62,78.24
Total	7,621,714	158	100.00	2.07	1.75,2.40	42,099	100.00	552.36	547.09,557.62
Unintentional Hospitalizations/Exposures									
Males	3,899,515	88	69.29	2.26	1.79,2.73	23,146	55.57	593.56	585.94,601.19
Females	3,722,199	39	30.71	1.05	0.72,1.38	18,372	44.11	493.58	486.46,500.70
0 to 4 years	1,928,473	103	81.10	5.34	4.31,6.37				
5 to 14 years	3,810,117	9	7.09	0.24	0.08,0.39				
15 to 19 years	1,883,124	15	11.81	0.80	0.39,1.20				
0 to 5 years	2,315,927					36,615	87.91	1,581.01	1,564.94,1,597.07
6 to 12 years	2,679,342					3,007	7.22	112.23	108.22,116.24
13 to 19 years	2,626,445					1,720	4.13	65.49	62.39,68.58
Total	7,621,714	127	100.00	1.67	1.38,1.96	41,650	100.00	546.47	541.23,551.70

Table 12 Continued

	Population Size[b]	Hospitalizations: Number of Cases	Percent of Cases	Prevalence per 100,000	95% CI	Poison Center Exposures: Number of Cases	Percent of Cases	Prevalence per 100,000	95% CI
Intentional Hospitalizations/Exposures									
Males	3,899,515	16	51.61	0.41	0.21,0.61	250	55.68	6.41	5.62,7.21
Females	3,722,199	15	48.39	0.40	0.20,0.61	194	43.21	5.21	4.48,5.95
0 to 4 years	1,928,473	0	0.00	0.00	0.00,0.00				
5 to 14 years	3,810,117	2	6.45	0.05	0.02,0.13				
15 to 19 years	1,883,124	29	93.55	1.54	0.98,2.10				
0 to 5 years	2,315,927					84	18.71	3.63	3.17,4.67
6 to 12 years	2,679,342					105	23.29	3.92	3.17,4.67
13 to 19 years	2,626,445					248	55.23	9.44	8.27,10.62
Total	7,621,714	31	100.00	0.41	0.26,0.55	449	100.00	5.89	5.35,6.44

[a] For poison center exposures there are 137 unknown sex and 320 unknown ages

[b] Population data for children age ≤ 19 years was obtained from the United States Census Bureau (USCB) using 2010 decennial data.

Table 13 Frequency and Percentage of Pesticide-Related Hospitalizations and Pesticide-Related Poison Center Exposures in Children ≤19 years by Year, 2004-2013

		Hospitalizations				Poison Center Exposures			
	Population[a]	Number of Cases	Percent of Cases	Prevalence per 100,000	95% CI	Number of Cases	Percent of Cases	Prevalence per 100,000	95% CI
All Hospitalizations/Exposures									
2004	6,870,155	22	13.92	0.32	0.19,0.45	5,300	12.59	77.15	75.07,79.22
2005	6,941,942	16	10.13	0.23	0.12,0.34	5,026	11.94	72.40	70.40,74.40
2006	7,097,649	17	10.76	0.24	0.13,0.35	4,517	10.73	63.64	61.79,65.50
2007	7,173,065	13	8.23	0.18	0.08,0.28	4,469	10.62	62.30	60.48,64.13
2008	7,250,251	14	8.86	0.19	0.09,0.29	4,492	10.67	61.96	60.15,63.77
2009	7,331,998	16	10.13	0.22	0.11,0.33	4,098	9.73	55.89	54.18,57.60
2010	7,621,714	23	14.56	0.30	0.18,0.43	3,858	9.16	50.62	49.02,52.22
2011	7,732,596	16	10.13	0.21	0.11,0.31	3,508	8.33	45.37	43.87,46.87
2012	7,816,119	13	8.23	0.17	0.08, 0.26	3,578	8.50	45.78	44.28,47.28
2013	7,833,335	8	5.06	0.10	0.03,0.17	3,253	7.73	41.53	40.10,42.95
Total	7,621,714	158	100.00	2.07	1.75,2.40	42,099	100.00	552.36	547.09,557.62
Unintentional Hospitalizations/Exposures									
2004	6,870,155	18	14.17	0.26	0.14,0.38	5,270	12.65	76.71	74.64,78.78
2005	6,941,942	12	9.45	0.17	0.08,0.27	4,982	11.96	71.77	69.77,73.76
2006	7,097,649	14	11.02	0.20	0.09,0.30	4,479	10.75	63.11	61.26,64.95
2007	7,173,065	10	7.87	0.14	0.05,0.23	4,411	10.59	61.49	59.68,63.31
2008	7,250,251	11	8.66	0.15	0.06,0.24	4,440	10.66	61.24	59.44,63.04
2009	7,331,998	13	10.24	0.18	0.08,0.27	4,061	9.75	55.39	53.68,57.09
2010	7,621,714	18	14.17	0.24	0.13,0.35	3,807	9.14	49.95	48.36,51.54
2011	7,732,596	13	10.24	0.17	0.08,0.26	3,455	8.30	44.68	43.19,46.17
2012	7,816,119	11	8.66	0.14	0.06,0.22	3,531	8.48	45.18	43.69,46.67

Table 13 Continued

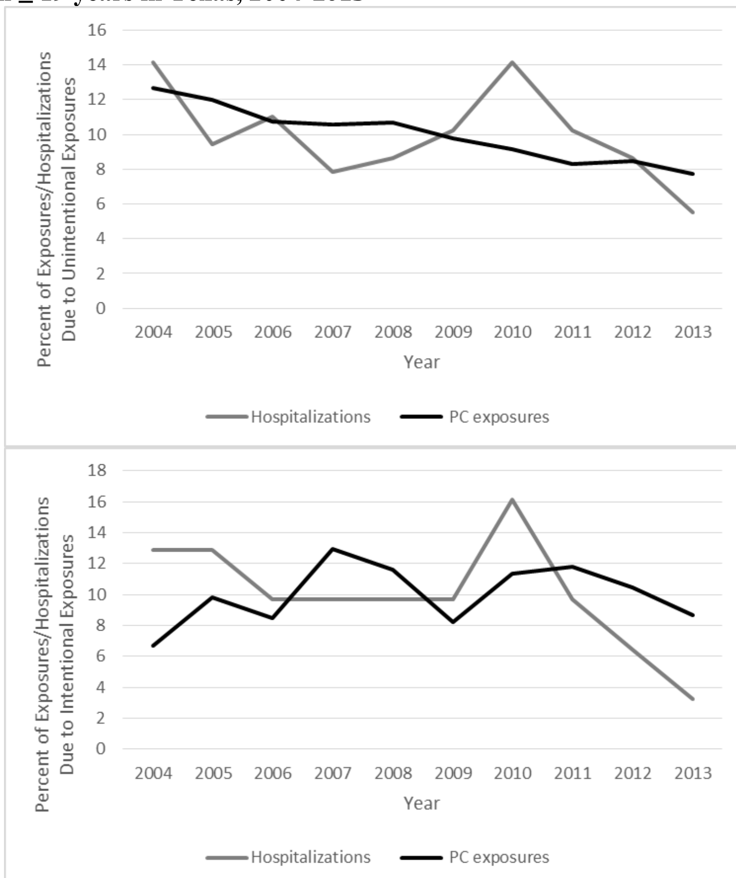
		Hospitalizations				Poison Center Exposures			
	Population[a]	Number of Cases	Percent of Cases	Prevalence per 100,000	95% CI	Number of Cases	Percent of Cases	Prevalence per 100,000	95% CI
2013	7,833,335	7	5.51	0.09	0.02,0.16	3,214	7.72	41.03	39.61,42.45
Total	7,621,714	127	100.00	1.67	1.38,1.96	41,650	100.00	546.47	541.23,551.70
Intentional Hospitalizations/Exposures									
2004	6,870,155	4	12.90	0.06	0.00,0.12	30	6.68	0.44	0.28,0.59
2005	6,941,942	4	12.90	0.06	0.00,0.11	44	9.80	0.63	0.45,0.82
2006	7,097,649	3	9.68	0.04	-0.01,0.09	38	8.46	0.54	0.37,0.71
2007	7,173,065	3	9.68	0.04	-0.01,0.09	58	12.92	0.81	0.60,1.02
2008	7,250,251	3	9.68	0.04	-0.01,0.09	52	11.58	0.72	0.52,0.91
2009	7,331,998	3	9.68	0.04	-0.01,0.09	37	8.24	0.50	0.34,0.67
2010	7,621,714	5	16.13	0.07	0.01,0.12	51	11.36	0.67	0.49,0.85
2011	7,732,596	3	9.68	0.04	-0.01,0.08	53	11.80	0.69	0.50,0.87
2012	7,816,119	2	6.45	0.03	-0.01,0.06	47	10.47	0.60	0.43,0.77
2013	7,833,335	1	3.23	0.01	-0.01,0.04	39	8.69	0.50	0.34,0.65
Total	7,621,714	31	100.00	0.41	0.26,0.55	449	100.00	5.89	5.35,6.44

[a] Annual population data for children ≤ 19 years was obtained from the Texas Department of State Health Services (DSHS) using census population and intercensal estimates

an average of 4,165 annually with a range of 3,214 to 5,270. The average annual prevalence rate for pesticide-related hospitalizations was 0.22 per 100,000; whereas the average annual prevalence rate for pesticide-related poison center exposures was 57.66 per 100,000. There was an average of 3.1 intentional pesticide-related hospitalizations with a range of 1 to 5; for intentional pesticide-related poison center exposures, there was an average of 44.9 annually with a range of 30 to 58. Figure 5 displays the percentage of pesticide-related hospitalizations and poison center exposures by year and intent. There was a decline in unintentional pesticide-related hospitalizations and unintentional pesticide-related poison center exposures. There appears to be a decline for intentional pesticide-related hospitalizations, but there appears to be a slight increase in intentional pesticide-related poison center exposures. In addition, both datasets reported fatal exposures. There were four fatal cases in hospitalization data and there were two fatal cases identified in the poison center data (data not shown).

Analysis of the correlation between the two datasets showed that overall pesticide-related hospitalizations and poison center exposures were moderately positively correlated at the state level (R=0.48, p-value=0.1570) (data not shown). Unintentional pesticide-related hospitalizations and unintentional pesticide-related poison center exposures were found to be moderately positively correlated at the state level (R=0.43, p-value=0.2112) (data not shown). However, for intentional pesticide-related hospitalizations and intentional pesticide-related poison center exposures, there was no correlation at the state level (R=0.07, p-value=0.8476) (data not shown).

Figure 5 Percent of Pesticide-Related Hospitalizations and Poison Center Exposures by Year and Intent in Children ≤ 19 years in Texas, 2004-2013



5.4. Discussion

The two datasets showed sex differences in all pesticide exposures. A comparison of the two datasets shows that males overall have an increased risk of childhood pesticide exposures. This finding is supported by a 2008 World Health Organization (WHO) report on childhood injury prevention which found males typically had higher rates of poisonings compared to females (Peden et al. 2008). This is believed to be a result of differences in socialization (WHO 2008). However, at this time there is no literature that addresses how socialization would impact poisoning differences between genders. The present study also found that younger children are more at risk for unintentional pesticide exposures, whereas older children are at increased risk of intentional pesticide exposures, a finding consistent with the 2008 WHO report (Peden et al. 2008). This is believed to be due to the curiosity and behaviors (e.g., mouthing behavior) of younger children and adolescents being more likely to intentionally misuse poisons (WHO 2008).

The present study also found that both unintentional pesticide-related hospitalizations and pesticide-related poison center exposures, and intentional pesticide-related hospitalizations, decreased from 2004-2013. At this time, there is no explanation for this, and it is unclear whether this trend will continue. Spiller and colleagues (2013) found that poison center data was strongly associated with live birth counts. The authors found that positive and negative changes in live birth counts were reflected in poison center exposures in children <6 years (Spiller et al. 2013). Thus, birth counts may explain decreases in reported pesticide-related poison center exposures, which would potentially result in decreased hospitalizations. The association with live births and poisonings should be further researched to explain potential declines in exposures. The study also found overall and unintentional pesticide-related hospitalizations and pesticide-related poison center exposures were moderately correlated at the state level; however, these were not significant. Future research should be conducted at lower geographic levels (e.g. county, census block, or census tract) to determine if these exposures are significantly correlated.

The two datasets have differences in the type of data and information they contain due to the nature and purposes of the data collected. First, inpatient hospitalization records contain information on hospital discharges; whereas, poison center data contain information on calls made to the TPCN. Pesticide-related poison center exposures are voluntarily reported and only include information that is self-reported by the caller. Poison center data are unique compared to other datasets in that the data is immediately available and useful for trend monitoring (Simone and Spiller 2010). Both datasets include variables on sex, age, and intent (diagnosis codes and reason for exposure). There are differences in the available variables between the two datasets. The hospitalization data include type of admission, associated costs, length of stay, race, and ethnicity; while poison center data include variables on reported exposure substance, exposure route, medical outcome, and management site. Another potential difference between the two datasets would be utilization of services. There are many studies that have found that certain populations are least likely to utilize poison centers, such as African Americans and those who speak a language besides English (Forrester 2005; Litovitz et al. 2010). Utilization factors such as insurance status may also impact hospital use. Thus, differences in populations served may impact both datasets and should be researched further.

Both datasets provide information on the burden of pesticide exposures on children in Texas. Through utilizing both datasets, exposures that result in poison center calls and hospitalizations can be characterized. Specifically, this allows for cases of lesser and greater severity to be captured. However, the full burden of pesticide exposures and associated illnesses in children is unknown due to data limitations. Hospitalization data limitations are that visits to urgent care, primary care physicians, and emergency rooms are not included in the dataset. Poison center data have limitations (e.g., only calls to the center are captured). In addition, data collected during poison center calls are voluntary and self-reported, potentially leading to missing data or reporting bias that may lead to underestimates of exposure. Poison center data captures information on reported exposures and the AAPCC states the data should not be assumed to represent all exposures (Mowry et al. 2015). This is supported by a comparison of National Health Interview Survey (NHIS) and poison center data, which found that for children <6 years, 14%-30% of exposures reported to NHIS were reported to poison centers (Polivka et al. 2002). Next, potential misclassification is feasible with both datasets. For example, regarding hospitalizations E-code, E861.4 is for disinfectants, which would include the substance formaldehyde. Formaldehyde is used in building materials, household products, and pesticides (PAN 2016). In addition, if the wrong Poisindex code is utilized pesticide-related poison center exposures can potentially be misclassified. Another limitation is that it is not possible to determine if the same child has repeated exposures throughout the time period for each dataset, or whether the datasets are capturing the same exposures. At this time, it is not feasible to determine if a child is being included in both hospitalization and poison center data. Third, a significant limitation of both datasets is that they only capture acute exposures, while they miss chronic exposures, especially those that are low dose, and their long term consequences. Both datasets provide only a snapshot into pesticide exposures.

Another limitation of comparing the two datasets is that the available age categories are not directly comparable between the datasets.

Additional research is needed to understand the burden of pesticide exposures and associated health effects in children throughout the U.S. This study demonstrates that secondary data sources can be used to begin to quantify the burden of pesticides in children in Texas. However, other secondary data sources may prove to be beneficial in quantifying the burden of pesticide exposures and associated illnesses in children, such as cancer registries, emergency room data, and mortality data. For example, mortality data may prove to be helpful when examining fatal poisoning cases because poison center data are likely to underrepresent fatal cases, and this underrepresentation may be true for hospitalization data as well (Blanc et al. 1995; Hoppe-Roberts et al. 2000; Linakis and Frederick 1993). For example, Hoppe-Roberts and colleagues (2000) compared mortality data with poison center data and found that there were 16,527 poisoning deaths in mortality data and 766 poisoning deaths in the poison center data. In addition, if secondary datasets could be linked together, that would prove helpful for checking data accuracy (Hoyt et al. 1999). Potential limitations may be overcome through utilization of multiple linked datasets. A potential linked study could include hospitalization data and poison center data. This would make it possible to characterize exposure information from poison centers and detailed health outcome information from hospitalization data. For example, if hospitalization records could be linked to poison center data, it would be possible to examine exposure routes for hospitalizations that were also reported to poison centers. This would provide information that could be utilized to understand the severity of the exposures that resulted in hospitalizations, as well as associated health effects which may result in better treatment. The present study was able to describe acute pesticide exposures and trends captured from 2004-2013 utilizing both datasets. This allows researchers to characterize childhood pesticide exposures utilizing hospitalization and poison center data, as well as the strengths and limitations of utilizing multiple secondary datasets.

5.5. Conclusions

This study compared findings from pesticide-related hospitalizations and pesticide-related poison center exposures to characterize the burden of pesticide exposures on children ≤ 19 years in Texas. This study also compared the strengths and limitations of both datasets. Despite data limitations, each dataset proved to be useful in characterizing pesticide-related exposures in children. This is important because there is not one surveillance dataset that captures all exposures; thus, multiple datasets need to be utilized to quantify the burden of pesticide exposures. Future research should consider utilizing other secondary datasets to better quantify the burden of pesticides on children, such as mortality data which would capture fatal exposures not captured through poison center and hospitalization data (Blanc et al. 1995; Hoppe-Roberts et al. 2000; Linakis and Frederick 1993). Lastly, the benefits of linking available datasets would allow for the accuracy of data to be verified, and would allow for variables not available to be tied into future analysis (Hoyt et al. 1999).

6. AN EXPLORATORY STUDY OF SPATIAL CLUSTERS OF UNINTENTIONAL PESTICIDE-RELATED POISON CENTER EXPOSURES AND RELATED FACTORS

6.1. Introduction

Pesticide exposures result in millions of acute poisoning cases a year worldwide, with approximately 1 million resulting in a hospitalization (WHO 2004). Pesticides can impair neurologic and reproductive systems while also proving to be genotoxic (Sanborn et al. 2007). High and prolonged exposure is associated with various types of cancer (Bassil et al. 2007). In addition, children are more vulnerable to the health effects of pesticide exposures compared to adults due to a multitude of reasons, including that their bodies are still developing. Furthermore, the burden of exposures may be higher in children than in adults, even if exposed to the same concentration in the environment. Children breathe more per minute, have more skin surface relative to body weight, eat and drink more per unit body weight, and engage in behaviors that increase susceptibility (e.g., crawling on the ground and putting things in their mouths) (NPIC 2015).

Despite the known adverse health effects of pesticides and the increased susceptibility of children to these compounds, there is limited literature addressing the burden of pesticide exposures due to an overall lack of data from active surveillance systems (Roberts et al. 2012). A recent literature review discussed possible pesticide exposures and associated health effects, but provided little information on the prevalence of exposures (Roberts et al. 2012). In addition, there are a few studies that were published over a decade ago that examined pesticide exposures in children utilizing secondary data sources (Belson et al. 2003; Spann et al. 2000; Sumner and Langley 2000). Previous studies identified spatial clusters of pesticide exposures with severe outcomes (Sudakin et al. 2002; Sudakin and Power 2009). However, these studies did not identify why these clusters occurred (Sudakin et al. 2002; Sudakin and Power 2009). Existing research has found that the built environment can produce disparities, which may explain differences in environmental exposures, such as pesticide exposures (Cummins and Jackson 2001). Northridge and colleagues (2010) found that type of housing and housing quality were associated with childhood asthma in New York City. Through utilizing Geographic Information Systems (GIS) and identifying potential spatial clusters, this study adds to the existing research by assessing how pesticide-related exposures are spatially correlated in Texas. The specific objectives of this exploratory study are to: 1) to determine if unintentional pesticide-related exposures reported to Texas poison centers were spatially and/or temporally associated and 2) to explore the association between sociodemographic, built environment, stability, and other potentially related factors on unintentional pesticide-related poison center calls for children ≤19 years from 2000-2013. The first objective consists of two sub-aims: 1a) to identify clusters of higher than expected unintentional pesticide-related poison center exposures for children ≤19 years from 2000-2013 and 1b) to identify temporal trends for unintentional pesticide-related poison center exposures ≤19 years from 2000-2013.

6.2. Methods

6.2.1. Data Collection

The study included all unintentional exposures to pesticides that were reported to the Texas Poison Control Network (TPCN) for children ≤ 19 years from 2000-2013 with a reported caller county and known child age category. Age categories were defined using Association of Poison Control Centers (AAPCC) groupings, including children ≤ 5 years, children 6-12 years, and children 13-19 years. Calls classified as "child unknown" were excluded from the analysis. Next, 2005-2009 American Community Survey (ACS) 5-year estimates were used to assess potential variables associated with county-level clustering of unintentional pesticide-related poison center exposures (e.g. sociodemographic, built environment, and geographic mobility). To assess rurality and border, county designation data from the Texas Department of State Health Services (DSHS) was utilized (Texas DSHS 2015a). Lastly, annual population data for children ≤ 19 years was obtained from the Texas DSHS using census population and intercensal estimates (Texas DSHS 2015c). ACS variables were selected based on previous literature addressing utilization factors of poison centers and health disparities of poison centers. The following variables were included in the analysis education, poverty, income, race, foreign-born population, language spoken at home, average household size, housing occupancy, housing tenure, year structure built, and geographic mobility (Forrester 2005; Litovitz et al. 2010). The variable "mobility" was created, which summarizes all geographic mobility categories (e.g., moved same county, move different county, moved different state, moved abroad).

6.2.2. Data Analysis

First, Moran's I was obtained using ArcGIS 10.2.2. (ESRI, Redlands, CA) to assess for spatial autocorrelation, which determined if unintentional pesticide-related poison center exposures were spatially associated. Second, spatial scan statistic was used to identify nonrandom spatial clusters of unintentional pesticide-related poison center exposures in Texas using a discrete age-adjusted Poisson model with SatScan version 9.4 (Kulldorff M. and Information Management Services, Inc.). The spatial scan statistic calculates the expected number of cases for population size in each area to find areas that have higher than the expected number of cases (Kulldorff 2015). The model was age-adjusted using the AAPCC age groupings (children ≤5 years, children 6-12 years, and children 13-19 years). A limitation of the spatial scan statistic is that it has a low power to detect emerging cluster quickly; for example, if increased risk occurs during the last few years of a large time period, the purely spatial analysis will dilute the significance of the identified cluster due to time periods without increased risk being included (Kulldorff 2001). To address this limitation, two time periods were utilized (2000-2006 and 2007-2013). These time periods were large enough to utilize ACS 5-year estimates. In addition, through utilizing two smaller time periods, an analysis of clusters and associated variables was potentially able to capture differences that would not be captured in annual or smaller increments. Thus, to identify potential differences over time, the time period (2000-2013) was split into two periods (2000-2006 and 2007-2013). Descriptive statistics and significance tests (e.g., t-tests, Wilcoxon Sum Rank, and McNemar's tests) were conducted with STATA 14 SE (StataCorp LP, College Station, TX) to determine if potentially related factors were different for the identified cluster and non-cluster counties. T-tests were used for normally distributed continuous data; whereas Wilcoxon Sum Rank tests were used for non-parametric continuous data and McNemar's test were used for binary data. Bonferroni adjustment was utilized to control for the large number of significance tests. Two types of regression models were constructed to identify factors associated with clusters of exposures and with increasing prevalence of exposures.

Multiple logistic regression was utilized to assess the relationship between independent variables and the presence of cluster or non-cluster counties for each time period. Univariate analyses were used to build the models for both time periods with significant variables ($p < 0.05$) being included in the models. Backward selection was used to produce the most parsimonious model by dropping the highest p-value until all variables were significant ($p<0.05$). To confirm that all significant variables were included in the final model, those variables removed during univariate analyses and backward selection were included one at a time to establish the final models for each time period. Based on the final logistic models, the probability of being a cluster county was computed for each variable categorized into quartiles. This was done utilizing predictive margins in STATA 14 SE (StataCorp LP 2015).

Lastly, negative binomial regression was then utilized to look at prevalence of unintentional pesticide-related poison center exposures and potentially related variables. This allowed for the exploratory study to identify areas with higher and lower prevalence, instead of focusing specifically on cluster areas. Due to over-dispersion of the data, negative binomial regression was selected instead of Poisson regression. The same methods described above for logistic regression were utilized to build the model. Next, predicted prevalence was computed for each variable categorized into quartiles. This was done utilizing predictive margins in STATA 14 SE (StataCorp LP 2015). It is important to note that predicted margins for logistic regression show the predicted probability of being a cluster county, and for negative binomial regression, predicted margins display the predicted prevalence of unintentional pesticide-related poison center exposures.

The research was deemed not to involve human subjects by the Texas DSHS Institutional Review Board (IRB) (IRB#14-064) and the research was deemed exempt by the Texas A&M University IRB (IRB 2015-0563M).

6.3. Results

From 2000 to 2013, there were 59,477 unintentional pesticide-related exposures reported to a Texas poison center that met the case definition and had a reported caller county and age (excluded cases=1,050 [location=657 and age=393]). The Moran's I was 0.12 (z-score=5.07, p- value ≤ 0.01), indicating that unintentional pesticide-related poison center exposures were spatially clustered. Spatial autocorrelation showed that the prevalence rates for Time Period 1 and Time Period 2 were significantly clustered ($p<0.01$). The average annual age-adjusted rate for unintentional pesticide-related poison center exposures was 59.2 per 100,000 population. For children $\leq$ 19 years in Texas, the spatial scan analysis identified primary clusters of higher than expected rates of unintentional pesticide-related poison center exposures for the two time periods (see

Figure 6 and Table 14). The spatial scan statistic identified 59 counties in the primary cluster for Time Period 1, and 119 counties in the primary cluster for Time Period 2. It is important to note that the cluster for Time Period 2 appears to shift slightly from Time Period 1 to the west; there are 4 counties in the cluster for Time Period 1 that are no longer cluster counties in Time Period 2. The average annual age-adjusted rate was 69.6 per 100,000 population for Time Period 1, and 49.9 per 100,000 population for Time Period 2. In addition, the relative risk differed between the two time periods, and was 1.90 for Time Period 1 and 1.75 for Time Period 2.

Figure 6 Age-Adjusted Primary Spatial Clusters of Texas Poison Center Calls Regarding Unintentional Pesticide-Related Exposures among Children ≤19 years in Texas from 2000-2013

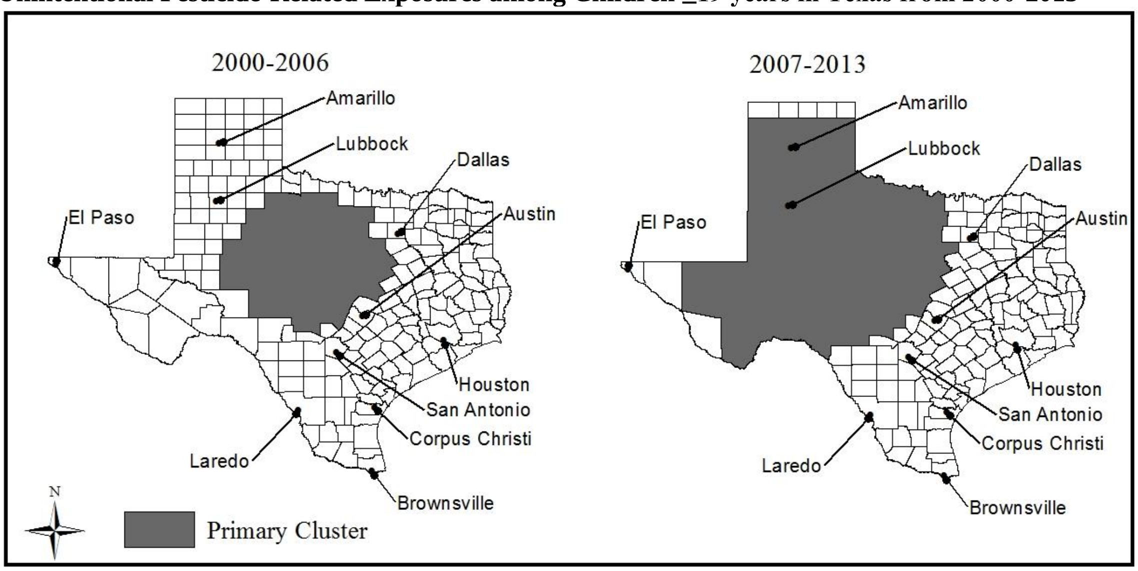


Table 14 Unintentional Pesticide-Related Poison Center Exposures among Children ≤19 years: Age-Adjusted Primary Spatial Clusters by Time Period

	No. of Observed Cases	No. of Expected Cases	No. of Counties	Annual Cases per 100,000	Relative Risk	p-value
Time Period 1 (2000-2006)	3,650.00	2,025.89	59	69.6	1.90	<0.01
Time Period 2 (2007-2013)	4,285.00	2,636.12	119	49.9	1.75	<0.01

Tables 15 and 16 display the means and p-values for t-tests, Wilcoxon Sum Rank tests, and McNemar tests with and without Bonferroni adjustment by cluster classification for potential associated variables. The state mean values were also provided for comparison to compare cluster classification means to state means. When compared to the Texas average, cluster counties for both time periods had a higher mean percent of population that were high school graduate, population that finished some college, population that completed a bachelor's degree, population that was white, vacant structures, structures built before 1939, structures built between 1940-1949, structures built between 1950-1959, structures built between before 1969, and rural counties. Next, for Time Period 1, variables that were significantly different between cluster and non-cluster counties included percent of less than 9th grade, some college, bachelor degree, high school graduate or higher, bachelor's degree or higher, families below the poverty level, white, black or African American, native Hawaiian, Hispanic, foreign born population, language other than English spoken at home, vacant housing, average household size, structures built before 1939, structures built between 1990-

1999, structures built before 1969, structures built after 1970, rural, and border designation (see Table 15). For Time Period 2, variables that were significantly different between cluster and non-cluster counties included percent of population with an associate degree, white, black or African American, Asian, vacant housing, average household size, all of the variables addressing year structure built, rural, and border designation (see Table 16).

Table 15 Association between Potentially Associated Variables by Cluster Classification for Time Period 1 (2000-2006)[a]

	Cluster County	Non-Cluster County	p-value	Texas
	Mean (SD)			Mean (SD)
Education				
Less than 9th Grade	9.14 (4.49)	12.26 (7.06)	0.0028,[c,f]	11.53 (6.68)
High School Graduate	33.87 (4.16)	32.37 (6.17)	0.0801[b]	32.72 (5.79)
Some College	22.07 (3.65)	20.53 (4.04)	0.0086[c,f]	20.89 (4.00)
Associate Degree	5.58 (1.87)	5.54 (1.83)	0.8760[b]	5.55 (1.84)
Bachelor	12.68 (3.98)	11.71 (4.88)	0.0193[c,e]	11.93 (4.70)
Graduate/ Professional	4.92 (1.88)	5.10 (2.79)	0.5299[c]	5.06 (2.61)
High School Graduate or Higher	79.14 (5.50)	75.24 (8.91)	0.0021[c,f]	76.14 (8.40)
Bachelor's Degree or Higher	17.61 (5.16)	16.80 (7.30)	0.0309[c,e]	16.99 (6.86)
Income				
Percent of Families Below Poverty	10.98 (4.21)	14.43 (6.91)	0.0003[c,f]	13.63 (6.54)
Median Income	$42,038.12 ($7,309.88)	$41,456.20 ($10,925.60)	0.2420[c]	$41,591.37 ($10,190.30)
Mean Income	$56,112.80 ($8,189.21)	$55,114.26 ($12,636.00)	0.0987[c]	$55,346.20 ($11,746.75)
Race/Ethnicity				
White	86.89 (8.16)	80.51 (8.48)	0.0000[c,f]	81.99 (8.82)

Table 15 Continued

	Cluster County	Non-Cluster County	p-value	Texas
	Mean (SD)			Mean (SD)
Race/Ethnicity Continued				
Black or African American	3.12 (4.37)	7.62 (7.23)	0.0001[c,f]	6.66 (6.89)
American Indian or Alaska Native	0.57 (0.46)	0.65 (1.47)	0.2911[c]	0.63 (1.31)
Asian	0.53 (0.66)	0.91 (1.58)	0.0709[c]	0.82 (1.43)
Native Hawaiian	0.04 (0.11)	0.06 (0.18)	0.0293[c,e]	0.06(0.17)
Other Race	6.88 (5.16)	8.60 (7.06)	0.1566[c]	8.20 (6.70)
Hispanic	21.95 (11.84)	33.20 (24.39)	0.0097[c,f]	30.59 (98.63)
Percent Foreign Born Population	6.76 (5.10)	9.23 (6.90)	0.0080[c,f]	8.66 (6.60)
Language Other Than English	17.67 (9.84)	28.29 (21.20)	0.0017[c,f]	25.83 (19.68)
Built Environment				
Vacant Housing	24.62 (10.46)	19.77 (9.86)	0.0009[c,f]	20.90 (10.19)
Average Household Size	2.51 (0.27)	2.51 (0.31)	0.0003[c,f]	2.63 (0.30)
Renter Occupied	26.81 (7.97)	26.89 (7.00)	0.5802[c]	26.87 (7.22)
Age of Structures				
Percent Built Before 1939	14.58 (8.25)	9.75 (6.90)	0.0000[c,f]	10.87 (7.50)
Percent Built 1940-1949	8.32 (4.03)	7.75 (4.50)	0.1770[c]	7.89 (4.39)
Percent Built 1950-1959	14.00 (5.75)	12.86 (6.77)	0.0942[c]	13.12 (6.56)
Percent Built 1960-1969	11.86 (3.96)	12.79 (5.25)	0.2162[c]	12.57 (4.99)
Percent Built 1970-1979	16.54 (3.80)	17.55 (4.61)	0.1280[b]	17.31 (4.45)
Percent Built 1980-1989	15.56 (4.83)	16.15 (5.64)	0.4668[b]	16.01 (5.64)
Percent Built 1990-1999	11.41 (5.87)	13.75 (6.50)	0.0148[c,e]	13.20 (6.42)
Percent Built 2000-2004	5.72 (4.58)	6.97 (5.43)	0.1055[c]	6.68 (5.27)
Percent Built After 2005	2.01 (1.71)	2.43 (2.33)	0.3811[c]	2.33 (2.21)

Table 15 Continued

	Cluster County	Non-Cluster County	p-value	Texas
	Mean (SD)			Mean (SD)
Age of Structures Categories				
Percent Built Before 1969	48.76 (15.53)	43.15 (17.52)	0.0280[b,e]	44.46 (17.22)
Percent Built After 1970	51.24 (15.53)	56.85 (17.52)	0.0280[b,e]	55.54 (17.22)
Geographic Mobility				
Moved in Past 12 Months	16.80 (5.98)	16.46 (4.81)	0.8643[c]	16.54 (5.09)
County Classification				
Rural	0.75 (0.44)	0.66 (0.48)	0.0000[d,f]	0.68 (0.47)
Border	0.02 (0.13)	0.16 (0.37)	0.0042[d,f]	0.13 (0.33)

[a] Data obtained from ACS 5-year estimates and DSHS Border Designations
[b] t-test used for normally distributed data
[c] Wilcoxon rank-sum (Mann-Whitney) used for non-parametric data
[d] McNemars test used for binary data
[e]Significant $p \leq 0.05$
[f] Significant Bonferroni Adjusted $p<0.01$

Table 16 Association between Potentially Associated Variables by Cluster Classification for Time Period 2 (2007-2013)

	Cluster County	Non-Cluster County	p-value	Texas
	Mean (SD)			Mean (SD)
Education				
Less than 9th Grade	11.52 (6.00)	11.54 (7.25)	0.3430[c]	11.53 (6.68)
High School Graduate	33.01 (5.31)	32.45 (6.19)	0.4421[b]	32.72 (5.79)
Some College	20.92 (4.49)	20.86 (3.53)	0.9597[c]	20.89 (4.00)
Associate Degree	5.30 (1.84)	5.76 (1.81)	0.0473[b,e]	5.55 (1.84)
Bachelor	12.11 (4.24)	11.78 (5.08)	0.2137[c]	11.93 (4.70)
Graduate/Professional	4.75 (2.43)	5.33 (2.73)	0.0961[c]	5.06 (2.61)
High School Graduate or Higher	76.10 (8.00)	76.18 (8.77)	0.5160[c]	76.14 (8.40)
Bachelor's Degree or Higher	16.86 (6.00)	17.10 (7.55)	0.6342[c]	16.99 (6.86)
Income				
Percent of Families Below Poverty	12.64 (5.33)	14.50 (7.36)	0.1736[c]	13.63 (6.54)
Median Income	$41,259.94 ($8,678.16)	$41,883.52 ($11,382.37)	0.6756[c]	$41,591.37 ($10,190.30)
Mean Income	$54,841.55 ($9,502.31)	$55,791.04 ($13,438.31)	0.8100[c]	$55,346.20 ($11,746.75)
Race/Ethnicity				
White	85.75 (7.60)	78.67 (8.50)	0.0000[c,f]	81.99 (8.82)
Black or African American	3.34 (3.58)	9.59 (7.74)	0.0000[c,f]	6.66 (6.89)
American Indian or Alaskan Native	0.72 (1.83)	0.56 (0.52)	0.7280[c]	0.63 (1.31)
Asian	0.53 (0.61)	1.07 (1.84)	0.0033[c,f]	0.82 (1.43)
Native Hawaiian	0.06 (0.19)	0.06 (0.15)	0.0057[c]	0.06 (0.17)
Other Race	7.83 (5.48)	9.53 (7.62)	0.6869[c]	8.20 (6.70)
Hispanic	29.56 (17.62)	31.49 (26.26)	0.4099[c]	30.59 (98.63)
Percent Foreign Born Population	8.03 (6.02)	9.21 (7.05)	0.1847[c]	8.66 (6.60)
Language Other Than English	24.20 (15.34)	27.27 (22.79)	0.9959[c]	25.83 (19.68)

Table 16 Continued

	Cluster County	Non-Cluster County	p-value	Texas
	Mean (SD)			Mean (SD)
Built Environment				
Vacant Housing	23.57 (11.14)	18.54 (8.65)	0.0003[c,f]	20.90 (10.19)
Average Household Size	2.51 (0.25)	2.73 (0.32)	0.0000[c,f]	2.63 (0.30)
Renter Occupied	26.89 (6.98)	26.86 (7.45)	0.9257[c]	26.87 (7.22)
Age of Structures				
Percent Built Before 1939	14.07 (8.38)	8.06 (5.23)	0.0000[c,f]	10.87 (7.50)
Percent Built 1940-1949	10.05 (4.61)	5.98 (3.15)	0.0000[c,f]	7.89 (4.39)
Percent Built 1950-1959	16.78 (6.54)	9.90 (4.60)	0.0000[c,f]	13.12 (6.56)
Percent Built 1960-1969	14.21 (5.50)	11.12 (3.98)	0.0000[c,f]	12.57 (4.99)
Percent Built 1970-1979	16.38 (4.71)	18.14 (4.05)	0.0015[b,f]	17.31 (4.45)
Percent Built 1980-1989	13.24 (5.30)	18.46 (4.33)	0.0000[b,f]	16.01 (5.64)
Percent Built 1990-1999	9.50 (5.41)	16.47 (5.40)	0.0000[c,f]	13.20 (6.42)
Percent Built 2000-2004	4.26 (3.60)	8.81 (5.59)	0.0000[c,f]	6.68 (5.27)
Percent Built After 2005	1.49 (1.45)	3.07 (2.48)	0.0000[c,f]	2.33 (2.21)
Age of Structures Categories				
Percent Built Before 1969	55.12 (14.75)	35.06 (13.34)	0.0000[b,f]	44.46 (17.22)
Percent Built After 1970	44.88 (14.75)	64.94 (13.34)	0.0000[b,f]	55.54 (17.22)
Geographic Mobility				
Moved in Past 12 Months	16.52 (5.64)	16.55 (4.57)	0.7033[c]	16.54 (5.09)
County Classification				
0.78 (0.41)	0.58 (0.49)	0.0000[d,f]	0.68 (0.47)	
0.09 (0.29)	0.16 (0.36)	0.0000[d,f]	0.13 (0.33)	

[a] Data obtained from ACS 5-year estimates and DSHS Border Designations
[b] t-test used for normally distributed data
[c] Wilcoxon rank-sum (Mann-Whitney) used for non-parametric data
[d] McNemars test used for binary data
[e]Significant p≤0.05
[f] Significant Bonferroni Adjusted p<0.01

Next, the univariate analysis based on logistic regression identified significant variables for Time Period 1 and Time Period 2 that were associated with clustering of unintentional pesticide-related poison center exposures (see Table 17 and Table 18). Predicted margins show the probability of being a cluster county as the percentile of variables increase (See Figure 7 and 8). For both time periods, as the percentile increased for percent black or African American, the probability of being a cluster county decreased. In contrast, as the percentile increased for the percent of the population that had moved in past 12 months the probability of being a cluster county increased.

Table 17 Calls to Texas Poison Centers Regarding Unintentional Pesticide-Related Exposures among Children ≤ 19 years: Multiple Logistic Regression for Cluster Counties for Time Period 1 (2000-2006)[a]

	Odds Ratio (OR)	95% CI	p-value
Percent Black or African American Population	0.81	0.75,0.89	0.000
Percent Other than English Spoken at Home	0.93	0.90,0.96	0.000
Percent of Structures built 1990-1999	0.94	0.89,0.99	0.020
Percent of Population that has Moved Past 12 Months	1.08	1.01,1.16	0.022

[a] Pseudo R^2=0.2369

Table 18 Calls to Texas Poison Centers Regarding Unintentional Pesticide-Related Exposures among Children ≤ 19 years: Multiple Logistic Regression for Cluster Counties for Time Period 2 (2007-2013)[a]

	Odds Ratio (OR)	95% CI	p-value
Percent of Families Below Poverty Level	0.89	0.84,0.95	0.001
Percent White Population	1.13	1.05,1.21	0.000
Percent Black or African American Population	0.87	0.79,0.96	0.006
Percent of Structures Built Before 1969	1.13	1.09,1.16	0.000
Percent of Population that has Moved Past 12 Months	1.12	1.03,1.21	0.008

[a] Pseudo R^2=0.5083

Figure 7 Texas Poison Center Calls Regarding Unintentional Pesticide-Related Exposures in Children ≤ 19 years in Texas for Time Period 1 (2000-2006): Probability of Being a Cluster County for Significant Variables (Calculated using Logistic Regression)

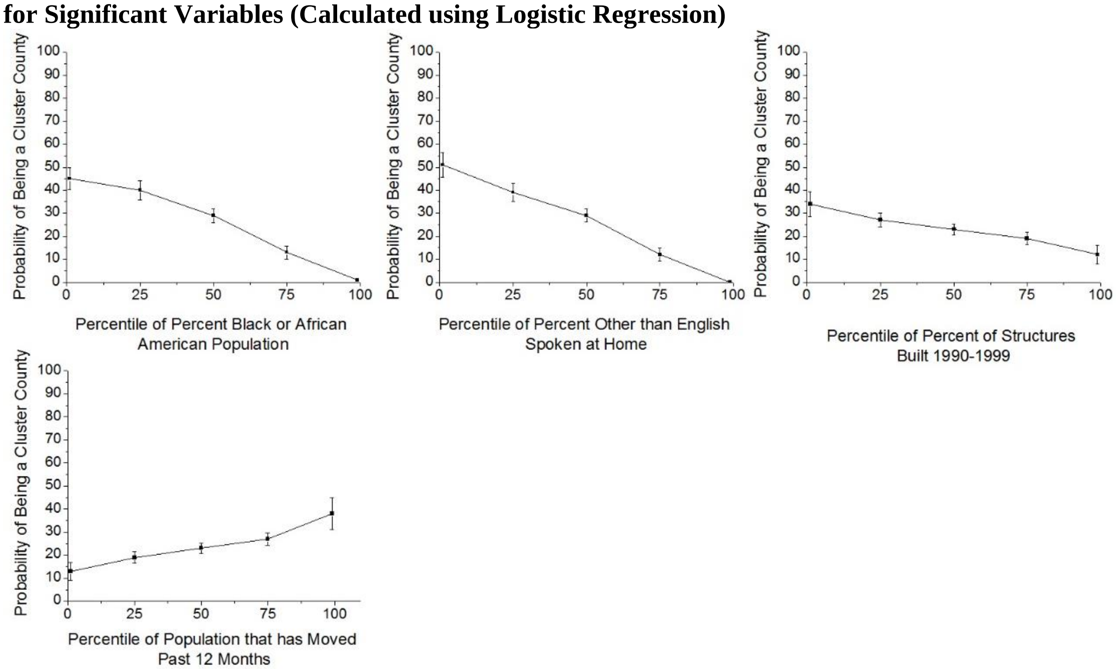
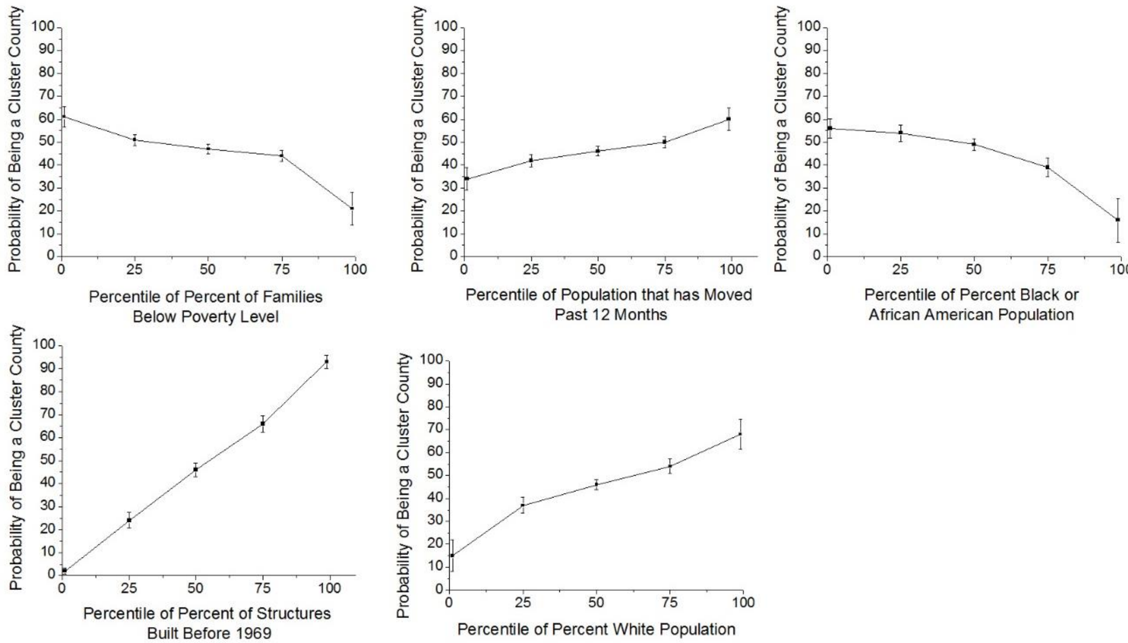


Figure 8 Texas Poison Center Calls Regarding Unintentional Pesticide-Related Exposures in Children ≤19 years in Texas for Time Period 2 (2007-2013): Probability of Being a Cluster County Significant Variables (Calculated using Logistic Regression)



Next, univariate analysis identified significant variables for Time Period 1 and Time Period 2 that were associated with the prevalence of unintentional pesticide-related poison center exposures (see Table 19 and Table 20). Predicted margins predict the expected rate as each variable percentile increases (See Figure 9 and Figure 10). For both time periods, as the percentile of percent American Indian or Alaska Native population increased, the predicted prevalence of unintentional pesticide-related poison center exposures decreased. In addition, as the percentile of structures built before 1939 increased, the predicted prevalence increased. Lastly, for both time periods, various education categories were associated with the prevalence of unintentional pesticide-related poison center exposures.

Table 19 Calls to Texas Poison Centers Regarding Unintentional Pesticide-Related Exposures among Children ≤ 19 years: Negative Binomial Regression for Time Period 1 (2000-2006)[a]

	IRR	95% CI	p-value
Percent with Bachelor's Degree or Higher	0.98	0.96,0.99	0.000
Percent of Population that Speaks Other Than English at Home	0.99	0.98,0.99	0.000
Percent Structures Built Before 1939	1.01	1.00,1.02	0.007
Percent American Indian or Alaska Native Population	0.84	0.76,0.94	0.002

[a] Pseudo R^2=0.0150

Table 20 Calls to Texas Poison Centers Regarding Unintentional Pesticide-Related Exposures among Children ≤ 19 years: Negative Binomial Regression for Time Period 2 (2007-2013)[a]

	IRR	95% CI	p-value
Percent with Associate Degree	0.96	0.92,0.99	0.026
Percent with Some College	1.04	1.02,1.06	0.000
Percent with Bachelor's Degree or Higher	0.99	0.97, 1.00	0.023
Percent of Families Below Poverty Level	0.97	0.95,0.98	0.000
Median Income	1.00	1.00,1.00	0.000
Percent American Indian or Alaska Native Population	0.86	0.79,0.93	0.000
Percent Structures Built Before 1939	1.02	1.01,.1.03	0.000
Percent of Population that has Moved Past 12 Months	1.02	1.00,1.03	0.019

[a] Pseudo R^2=0.0277

Figure 9 Texas Poison Center Calls Regarding Unintentional Pesticide-Related Exposures in Children ≤ 19 years in Texas for Time Period 1 (2000-2006): Predicted Rates of Pesticide Exposures for Significant Variables (Calculated using Negative Binomial Regression)

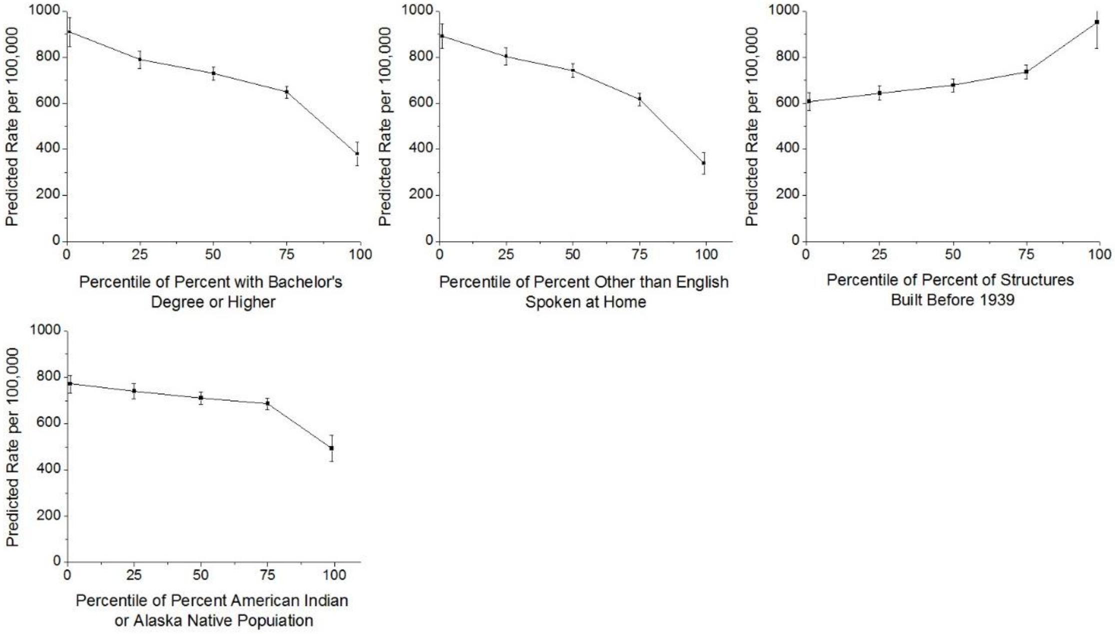
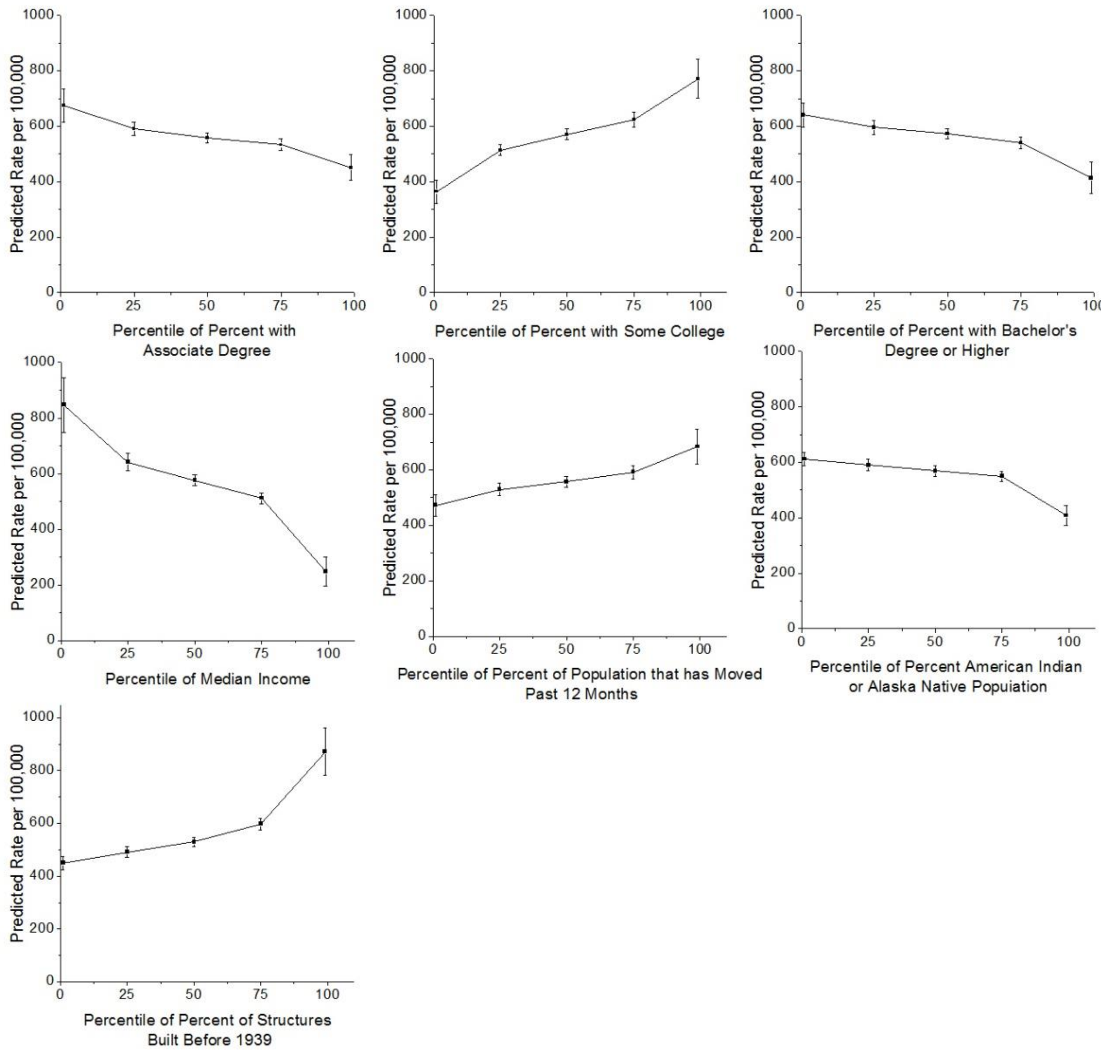


Figure 10 Texas Poison Center Calls Regarding Unintentional Pesticide-Related Exposures in Children ≤ 19 years in Texas for Time Period 2 (2007-2013): Predicted Rates of Pesticide Exposures for Significant Variables (Calculated using Negative Binomial Regression)



6.4. Discussion

This exploratory study found that unintentional pesticide-related poison center exposures for both time periods were significantly clustered. This indicates spatial association of unintentional pesticide-related poison center exposures which supports that geography or factors related to geography played a role in unintentional pesticide-related poison center exposures. It also identified primary spatial clusters for the two time periods, 2000-2006 and 2007-2013. The primary cluster for Time Period 2 (n=119 counties) had approximately twice the number of counties included in the primary cluster for Time Period 1 (n=59 counties). The cluster for Time Period 2 included 64 counties not included in the Time Period 1 cluster. A potential explanation for the growth and slight shift of the primary cluster is that the annual average rate of unintentional pesticide-related poison center exposures decreased for 2007-2013, which means the expected rate also decreased. Thus, the threshold for a county being included in a cluster decreased over time.

This exploratory study then utilized ACS data and county designation data to explore potentially related factors associated with unintentional pesticide-related poison center exposures in children ≤19 years. The logistic regression models found that percentage of population that moved in the past 12 months was significantly associated with clusters of unintentional pesticide-related poison center exposures. At this time there is limited literature discussing health and geographic mobility within the United States. Specifically, there is no literature addressing geographic mobility and environmental exposures, such as pesticides. A study addressing residential mobility in the United States found that those who moved were likely to be highly educated, younger, and in overall better health compared to those who stayed in same local area (Geronimus et al. 2014). Our findings and previous literature support the view that additional research is needed to study the association of geographic mobility and utilization of poison centers to report unintentional pesticide-related exposures. Next, for both time periods, percent black and African American had decreased odds of being a cluster county. This is supported by existing literature, which found counties with lower utilization rates had higher percentages of African American populations (Forrester 2005; Litovitz et al. 2010; Otuluka et al. 2015). In addition, the negative binomial regressions found percent of American Indian or Alaska Native was associated with increased prevalence of unintentional pesticide-related exposures. However, at this time there is no existing literature that examines this group's utilization of poison centers. Additional research is needed to understand this relationship. In addition, age of home seemed to be an important associated variable in both the logistic and negative binomial regression models. Age of home has been found to be a significant predictor of pesticide exposures. Offenberg and colleagues (2004) found homes built from 1945 to 1959 had the highest indoor concentrations of chlordane, an organochlorine, which is a common pesticide. Ward and colleagues (2009) found that dietary sources of pesticides have decreased substantially since the 1970s, but that older homes may be a major contributor to residential pesticide exposures because chemicals persist indoors where they are protected from degradation. Lastly, the negative binomial regression found that education had an association with the prevalence of unintentional pesticide-related poison center exposures. For Time Period 2, higher education (percent bachelor's degree or higher) was associated with a decrease in the prevalence which was also observed for Time Period 1; whereas some college was associated with an increase in the prevalence of unintentional pesticide-related poison center exposures. This is supported by Litovitz and colleagues (2010) who found lower educational levels were a barrier to poison center utilization. However, additional research is needed to understand the impact of education on unintentional pesticide-related poison center exposures.

The primary limitation of this study was that it was conducted using aggregated county-level data. Accordingly, findings need to be interpreted carefully to avoid the ecological fallacy and modifiable area unit problem (MAUP). This study may not have captured patterns that would be seen using smaller areas as the unit of analysis. Senyaki and Sattler (2013) found counties were too large as units of analysis to adequately show relationships when addressing potential sources of pollution; these researchers recommended census tracts or block groups. Next, a limitation of the spatial scan statistics is that the spatial analysis has a low power to detect quickly emerging clusters over extended periods of time (Kulldorff 2001). To respond to this limitation, the 14-year study period was split into two seven-year time periods. Another limitation is due to the use of poison center data, because this data is based on voluntary calls and self-reports. Poison center data only captures information for reported exposures and should not be assumed to represent all exposures to a substance (Mowry et al., 2015). Next, a limitation is that the caller county may differ from the exposure county for poison center calls. In addition, there may also be differences in reporting rates by social groups. For example, Forrester (2005) and Litovitz et al. (2010) found differences between overall utilization rates of poison centers according to race and income. Another limitation of the study design is that exposures without a location and age were excluded from the analysis, which may introduce bias.

The strengths of this exploratory study include utilization of both logistic and negative binomial regression. Logistic regression, allowed identification of potentially related variables for the clusters of counties identified in Time Periods 1 and 2. Next, negative binomial regression also made it possible to evaluate the association between potentially related variables and the prevalence of unintentional pesticide-related poison center exposures. Other strengths include the large number of unintentional pesticide-related poison center exposures in the data set and the long temporal period (2000-2013).

6.5. Conclusions

Through analyzing unintentional pesticide-related poison center exposures, census data, and county classification, this exploratory study was able to identify clusters, as well as examine the association of potentially related variables with identified clusters and prevalence rates. The information gained from this study should be utilized for future research to better understand why spatial clustering of unintentional pesticide-related poison center exposures occurs and to identify associated factors.

7. DISCUSSION AND CONCLUSION

7.1. Summary

This dissertation has focused on childhood residential exposures and associated factors that adversely affect health, with a particular emphasis on pesticide exposures. The three specific aims of this dissertation were:

1. Assess the changes in knowledge and self-reported behaviors associated with participation in an environmental health training provided for Webb County Head Start Center employees and parents. *This aim was addressed in Section 2 of this dissertation.*
2. Estimate the prevalence of intentional pesticide exposures (e.g., suicide and self-inflicted poisoning) among children age 19 years and under in the state of Texas utilizing the following secondary data: 1) Texas Poison Center pesticide-related calls for 2000-2013 and 2) Texas Inpatient Public Use Data File which includes pesticide-related hospitalizations from 2004-2013. *This aim was addressed in Sections 3, 4, and 5 of this dissertation.*
3. Estimate the prevalence of unintentional pesticide exposures (e.g., accidental ingestion of a pesticide) among children age 19 years and under stratified by demographics (including, gender and age) and other factors (e.g., types of pesticides) using two separate data sets, 1) Texas Poison Center data 2000-2013 and 2) Texas Inpatient Public Use Data File 2004-2013. This dissertation examined the potential association between health disparities (including, race/ethnicity, education, insurance coverage, income, rural or urban county classification, and border designation) and

unintentional childhood pesticide exposures. *This aim was addressed in Sections 3, 4, 5, and 6 of this dissertation.*

7.1.1. Addressing Specific Aims

The following sub-sections will discuss how the sections of this dissertation addressed the three specific aims outlined above.

7.1.1.1. Aim 1

Aim 1 was addressed through environmental health trainings conducted in Webb County, TX Head Start Centers (see Section 2). Through conducting environmental health trainings and collecting pre- and post-assessments changes in associated knowledge and self-reported behaviors were analyzed which allowed assessment of environmental health trainings.

7.1.1.2. Aim 2

Aim 2 was addressed through three sections of this dissertation (see Sections 3, 4, and 5). The purpose of Section 3 was to characterize pesticide-related hospitalizations in children $\leq$ 19 years in Texas. Next, the purpose of Section 4 was to characterize pesticide-related poison center exposures in in children $\leq$ 19 years in Texas. The ultimate goal of both sections was to understand the burden of pesticide exposures on children since there are no existing surveillance data to explain how many children are exposed. These sections were able to estimate the prevalence of intentional pesticide exposures (e.g., suicide and self-inflicted poisoning) in children $\leq$ 19 years in Texas through utilizing two state datasets (hospitalizations and poison center). In addition, Section 5, compared the two datasets, discussed the benefits of using these datasets when estimating prevalence of pesticide exposures, and discussed strengths, limitations, and future research needed for estimating pesticide exposures in children.

7.1.1.3. Aim 3

Aim 3 was covered in this dissertation through Sections 3, 4, 5, and 6. As mentioned above, sections 3 and 4 utilized hospitalization and poison center data to estimate the burden of unintentional pesticide exposures in children ≤ 19 years in Texas. In addition, Section 5, compared the two datasets, and discussed strengths, limitations and future research for estimating pesticide exposures in children. In addition, Section 6, utilized spatial scan statistics and regression methods to identify areas with higher than expected unintentional pesticide-related poison center exposures, as well as determine if census variables (e.g. sociodemographic and housing) at the county level were associated with unintentional pesticide-related poison center exposures. Section 6 addressed the second half of Aim 3 by looking at potential associated variables through descriptive statistics, significance tests (e.g., t-tests, Wilcoxon Sum Rank, and McNemar’s tests), and regression methods (e.g., logistic and negative binomial regression).

7.1.2. Summary of Findings

7.1.2.1. Head Start Environmental Trainings

This study provided environmental trainings that were attended by 560 Head Start parents and employees (Trueblood et al. 2016). Of those, 64 parents and 50 employees completed all questionnaires and were included in the data analysis (Trueblood et al. 2016). Pre- and post-assessments were utilized to determine if the environmental trainings were effective at improving environmental knowledge and self-reported behaviors (Trueblood et al. 2016). Paired t tests and McNemar tests were utilized with $p < 0.05$ considered significant (Trueblood et al. 2016). The mean scores for knowledge had significant changes immediately after the trainings (9.69 (95% CI 9.44. 9.94) and 10.58 (95% CI 10.42, 10.74), respectively) (Trueblood et al. 2016). Mean scores for self-reported behaviors had significant changes one month after the trainings (8.00 (95% CI 7.71, 8.29), 9.29 (95% CI 9.10, 9.48, respectively) (Trueblood et al. 2016). Overall, the pilot study found improved knowledge and self-reported behaviors following environmental health trainings in Head Start centers (Trueblood et al. 2016). The limitations of this study are discussed below (see section 7.3.1.1.).

7.1.2.2. Pesticide-Related Hospitalizations Descriptive Analysis and Prevalence Calculations

This study utilized THCIC hospitalization data to analyze pesticide-related hospitalizations for children ≤ 19 years in Texas from 2004-2013. For the study period, there were 158 pesticide-related hospitalizations. The prevalence for children ≤ 19 years was 2.07 per 100,000 for 2004-2013. Children 0-4 years old had the highest prevalence for unintentional exposures; whereas children aged 15-19 years old had the highest prevalence for intentional exposures. The study also found that males were more likely to be hospitalized due to pesticide exposures compared to females (65.82% and 31.18% of hospitalizations, respectively). In addition, based on ICD-9-CM and E-Codes, the most common pesticide categories associated with the hospitalizations were organophosphates/carbamates, disinfectants, rodenticides, and other pesticides (e.g.

pyrethrins/pyrethroids). In addition, of the hospitalizations, 80% were coded as having minor or moderate illness severity. The study found differences in the frequency of hospitalizations among sexes, age categories, and by intent (unintentional vs intentional). The limitations of this study are discussed below (see section 7.3.1.2.).

7.1.2.3. Pesticide-Related Poison Center Exposures Descriptive Analysis and Prevalence

Poison center data were utilized to analyze pesticide-related poison center exposures for children ≤ 19 years in Texas from 2000-2013. For the study period, there were 61,147 pesticide-related poison center exposures. The prevalence was highest among males at 864.24 per 100,000 population. The prevalence of unintentional exposures was highest among children aged ≤ 5 years at 2,310.69 per 100,000 population; whereas the prevalence of intentional exposures was highest among children aged 13 to 19 years at 13.82 per 100,000 population. Most exposures had medical outcomes that were classified as no effect (30.24%) or not followed, but minimal clinical effects possible (42.74%). Of all exposures, 81.24% were managed on site; however, for intentional exposures, 57.42% of these exposures were treated or referred to a health care facility. Overall the two common routes of exposure were ingestion (80.83%) and dermal (17.21%). The limitations of this study are discussed below (see section 7.3.1.3.).

7.1.2.4. Comparison of Pesticide-Related Hospitalization and Poison Center Data

This study utilized poison center data and hospitalization data to compare the results from both and discuss the strengths and limitations of the two datasets. The two datasets showed gender differences in both pesticide-related hospitalizations and poison center exposures; for both datasets, males had a higher proportion of hospitalizations and poison center exposures. Next, young children had a higher proportion of unintentional pesticide-related hospitalizations (children $\leq$ 4 years) and poison center exposures (children $\leq$ 5 years). In contrast, adolescents had higher proportions of intentional pesticide-related hospitalizations (children aged 15 to 19 years) and poison center exposures (children aged 13 to 19 years). Over the time period studied, both pesticide-related hospitalizations and pesticide-related poison center exposures decreased. Lastly, the study found overall pesticide-related hospitalizations and poison center exposures were moderately positively associated (R=0.48). The limitations of this study are discussed below (see section 7.3.1.4.).

7.1.2.5. Spatial Analysis and Associated Factors

This study utilized unintentional pesticide-related poison center data to determine if exposures are spatially or temporally associated, identify clusters of higher than expected exposures, and explore the association of potentially related factors. This was done through a spatial scan analysis, descriptive statistics, significance tests (e.g., t-tests, Wilcoxon Sum Rank, and McNemar's tests) logistic regression models and negative binomial regression models. The study found that percent black or African American population was protective and percent of population that moved in past 12 months was significantly associated with clusters of unintentional pesticide-related poison center exposures in children $\leq$19 years in Texas. Negative binomial regression models identified potentially related factors associated with rates of unintentional pesticide-related poison center exposures in children $\leq$19 years which found percent of structures built before 1939 were positively associated and percent American Indian or Alaska Native population were protective. The limitations of this study are discussed below (see section 7.3.1.5.).

7.2. Public Health Relevance

This dissertation addressed childhood residential exposures and associated factors with a focus on pesticide exposures. The 2014 American Association of Poison Control Centers National Poison Data System (AAPCC NPDS) showed that pesticide exposures were the 8th most commonly reported substance category for children ≤ 5 years (Mowry et al. 2015). Pesticides are a common solution to many public health problems, such as vector-borne diseases, rodent-borne diseases, and agricultural pests (U.S. EPA 2016a). However, although pesticides are a solution to multiple public health problems, pesticide exposures are associated with a variety of adverse health outcomes and result in a different public health issue.

The research of this dissertation attempts: 1) to understand if environmental trainings are effective at improving knowledge and self-reported behaviors associated with common exposures, 2) to understand the burden of pesticide exposures on children in Texas, and 3) to understand potential health disparities associated with pesticide exposures. This research addresses many of the ten Public Health Essential Services (CDC 2016). First, through calculating the prevalence of pesticide-related hospitalizations and poison center exposures we are **monitoring** and **investigating** environmental public health problems (CDC 2016). Second, through characterizing pesticide exposures in children and adolescents this dissertation helped **diagnose and**

investigate health hazards. Third, through conducting and evaluating environmental health trainings, the research was able to **inform, educate, and empower** study participants about environmental public health issues (CDC 2016). Fourth, we conducted **research** utilizing secondary datasets to examine the burden of pesticides on children, as well as through conducting assessments on environmental health trainings (CDC 2016). Next, through studying health disparities and utilization factors of pesticide-related poison center exposures, this research attempts to understand factors that impact utilization of poison centers. Through understanding utilization barriers, the information obtained can be used to **link** those with lower utilization factors to poison centers, such as through targeted poison center campaigns in areas with lower utilization rates (CDC 2016).

In addition, environmental issues contribute substantially to many adverse health effects of public health concern. It is estimated that globally, 25% of all deaths and the total disease burden can be attributed to environmental factors (ODPHP 2016). There are six environmental objectives in Healthy People 2020, which include 1) outdoor air quality, 2) surface and ground water quality, 3) toxic substances and hazardous wastes, 4) homes and communities, 5) infrastructure and surveillance, and 6) global environmental health (ODPHP 2016). This dissertation addresses three of the objectives. First, the dissertation researches childhood environmental exposures, with a focus on pesticide exposures. Pesticides are classified as **a toxic substance or hazardous waste** which according to the objectives need to be further investigated (ODPHP 2016). Second, the dissertation addressed residential exposures (**homes and communities**) that can affect health and safety (ODPHP 2016). Lastly, this dissertation largely utilizes secondary data (**infrastructure and surveillance)** to understand pesticide-related exposures, and suggests future research utilizing surveillance data to monitor pesticide exposures (ODPHP 2016).

7.3. Summary of Limitations and Future Directions

Limitations and future directions have been discussed in greater detail in each of the previous research sections of this dissertation (Sections 2-6). This section will provide a brief overview of limitations and future directions.

7.3.1. Limitations

7.3.1.1. Head Start Environmental Trainings

The most significant limitation of the Head Start Environmental Trainings was that no demographic data was collected which impacted the ability to assess the association of socioeconomic factors (Trueblood et al. 2016). Next, behavioral changes were self-reported which may have resulted in recall bias (Trueblood et al. 2016). Lastly, there was a relatively small sample size, which did not allow for differences in parents and employees to be analyzed (Trueblood et al. 2016).

7.3.1.2. Pesticide-Related Hospitalizations Descriptive Analysis and Prevalence

One limitation of the hospitalization study was that the study only captured acute exposures and hospitalizations, thereby missing chronic exposures and visits to urgent care centers, primary care physicians, and emergency rooms. In addition, Badakhsh and colleagues (2010) found that ICD-9-CM and E-Codes might not capture all hospitalizations. Another limitation is potential misclassification of cases.

7.3.1.3. Pesticide-Related Poison Center Exposures Descriptive Analysis and Prevalence

The limitations of this section are that poison center data only captures reported exposures; thus, does not represent all exposures. Poison center data acts as a snapshot in time. In addition, poison center data only capture acute exposures, which misses chronic exposures and long-term consequences. Another important limitation is potential misclassification of exposures.

7.3.1.4. Comparison of Pesticide-Related Hospitalization and Poison Center Data

There are several limitations when comparing these two datasets. One is that there are differences in the defined age categories. There is also potential misclassification of data in both datasets. In addition, there is no way to determine if there are repeated exposures, such as if a child appears more than once in one of the two datasets, or whether the same exposure appears in both datasets. Lastly, both datasets only capture acute exposures, while they miss chronic exposures and long-term consequences.

7.3.1.5. Spatial Analysis and Associated Factors

The primary limitation of this study was that it utilized aggregated data at cluster level and county level, which may result in the ecological fallacy or modifiable area unit problem. In addition, there are limitations with the methods used, for example, the spatial scan statistic has a low power to detect emerging clusters quickly for large study periods. Another significant limitation is that poison center data is self-reported and voluntary; poison center data only captures information for reported exposures and does not represent all exposures (Mowry et al. 2015). A final limitation is that the study excluded exposures without a location and age, which may result in bias.

7.3.2. Future Directions

This dissertation attempted to understand the effectiveness of environmental health trainings on associated knowledge and self-reported behaviors, and to characterize the burden of pesticides on children in Texas. The study of the effectiveness of environmental health training was a pilot study, and additional research is needed to address the effect of potential confounders (age, gender, willingness to participate) on the impact of knowledge and self-reported behaviors (Trueblood et al. 2016). In addition, more research is needed in other communities and settings to assess the effectiveness of environmental health trainings. Next, the dissertation utilized two datasets (hospitalizations and poison center) to understand the burden of pesticides on children. Future research should focus on understanding the overall burden of childhood pesticide exposures through other available datasets (e.g. cancer registries, mortality, emergency room data). In addition, future research should go beyond cross-sectional analysis to address childhood pesticide exposures and associated health effects. Next, the dissertation compared the pesticide-related hospitalization and poison center datasets, and discussed potential research utilizing secondary data. Future research involving secondary sets could attempt to link data and utilize other available datasets. Lastly, the dissertation identified potential spatial clusters of unintentional pesticide-related poison center exposures and associated variables through an exploratory study which found percent who moved in past 12 months was significant for county being a cluster county;

whereas, percent of structures built before 1939 was significant associated with higher rates of unintentional pesticide-related poison center exposures. The information gained from this exploratory study should be utilized for future research to understand why geography plays a role in pesticide-related exposures to help characterize clusters and areas with higher rates.

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