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A Pilot Study Of Arsenic In Young Children From Two Rural West Texas Communities: Blood Levels, Household Water Levels, And Behavioral Outcomes

Michelle Del Rio
University of Texas at El Paso, michelle61188@msn.com

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MICHELLE DEL RIO

Department of Public Health

APPROVED:

Christina Sobin, Ph.D., Chair

Maria Duarte-Gardea, Ph.D.

William Hargrove, Ph.D.

Charles Ambler, Ph.D.
Dean of the Graduate School

Dedication

I dedicate my work to the memory Dr. Paula Ford. Those who loved her and were inspired by her commitment to students and the community created the Paula Ford Scholarship Fund for students in Public Health at UTEP. I received this scholarship and it allowed me to learn about Dr. Hargrove's Health Impact Assessment in the town of Vinton, and became the start of my work on the Child Health Screening component of this project.

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By

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Abstract

Background & Significance: Heavy metals have been identified as a child health hazard because children are highly vulnerable to the effects of exposure, which can be physical, cognitive, and behavioral. Levels of arsenic (As) greater than the EPA Maximum Contaminant Level (10μg/L) were identified in some household water samples in two rural west Texas communities located within 20 miles of the U.S.-Mexico border by a Health Impact Assessment conducted in 2013 (Hargrove, Juarez-Carillo, & Korc 2015). Whether home water samples predicted child blood As levels needed to be examined. Since lead (Pb) is another common heavy metal contaminant in the border region, Pb was also examined.

Aims and Objectives: The goals of this study were to measure blood As and Pb levels in children; measure As and Pb in children's home water samples; and obtain parent-reported assessments of child behavior.

Hypotheses: H1): there is a linear relationship between arsenic in home water samples and child blood arsenic levels; H2): there is a linear relationship between lead in home water samples and child blood lead levels; H3): there is a linear relationship between child arsenic or lead levels and child behavior, as assessed by the child "Strengths and Difficulties Questionnaire" (Goodman & Goodman, 2012).

Methods: This was an observational study of 104 elementary school children ages 5 – 11 years, including 40 children from Community 1, whose families relied on water from domestic wells or privately owned wells made available to the public, and 64 children from Community 2, whose families relied on water from the municipal public water supply. Family demographics, child medical history, and child behavior assessments were collected from parents. Child As and Pb levels were determined from finger-stick blood samples analyzed using inductively coupled plasma mass spectrometry (ICP-MS). Household water samples were collected following EPA guidelines and analyzed also by ICP-MS.

Results: Blood As mean values for children from both schools exceeded the reference value of 1.2µg/dL (Mayo Clinic, 2014). Generalized mixed model linear regression analysis showed child blood As level was predicted by As household level ($F_{1/101}$= 4.71, p= 0.03), controlling for school as a random effect. Sex and age, and the sex by age interaction did not contribute significantly to the model. Models for Pb could not be conducted because most household water samples contained no detectable Pb. There was no association between children's blood As levels and behavior, controlling for age, sex, and school as a random effect.

Conclusion: Regardless of household water source (groundwater from domestic wells or privately owned wells made available to the public in Community 1 or water from the public municipal system in Community 2) children had blood As levels above the acceptable limit (1.2 µg/dL). Household water As levels predicted a significant proportion of variance in child blood As levels. For every one unit increase of As in home water samples (µg/dL), child blood As level increased by 0.26 µg/dL. A finding that may suggest that the current EPA Maximum Contaminant Level for As in drinking water (10µg/L) is not low enough to expose children to As. At the same time, the remaining unexplained variance in the model suggested that other sources of exposure are also contributing to child blood As levels.

Recommendations: As blood levels in children from these two communities must be monitored, and the other possible sources of contamination, such as soil and air, must be tested. Concerns of parents and teachers regarding child As exposure must be addressed in ongoing interactions with the communities and education about nutrition must be provided to the communities.

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Introduction

1.1 Heavy Metal Exposure is a Public Health Concern

Heavy metals are associated with higher rates of the most prevalent human diseases, such as respiratory, metabolic, and circulatory ones, including organ dysfunction and failure, and cancer (Solenkova, Newman, Berger, Thurston, Hochman, & Lamas, 2014; Martin, & Griswold, 2009). Because of the ill effects on health caused by heavy metals, they are reducing quality of life for humans. Some of the heavy metals of greatest concern for human health are arsenic, lead, mercury, cadmium, and aluminum. These heavy metals can cause many acute and chronic health outcomes at low and high levels of exposure. Because of their impact on human health, these heavy metals are monitored and regulated by agencies such as the Environmental Protection Agency (EPA), Toxic Substance and Abuse Disease Registry (ATSDR), National Center for Environmental Health, The National Institute for Occupational Safety and Health, and the Center for Disease and Control (CDC).

Concerns about heavy metals in the environment have grown following recognition that heavy metals are occurring in air, soil, water, and food supplies. Some heavy metals occur naturally in the earth's crust, as in the case of arsenic; others may be found near factory and industrial sites that produce heavy metals as waste (Bartrem et al., 2013; Evrenoglou et al., 2013; Landrigan & Baker, 1981). This type of contamination makes soil the most common source of exposure to heavy metals (Burges, Elpede, & Garbisu; 2015). The contamination in the soil also leads to contaminated groundwater sources (Defo, Palmer, Yerima, Noumsi, & Bemmo, 2015), vegetables and fruits (Lu, Song, Wang, Liu, Meng, Sweetman, Jenkins, Ferrier, Li, Luo, & Wang, 2015; Chung, Yu, & Hung, 2014). Yet, there are also other sources of exposure in everyday items, such as in homes built before 1980's who have leaded plumbing and indoor painting, in pottering glaze (Valles-Medina, Osuna-Leal, Martinez-Cervantez, Castillo-Fregoso, Vazquez-Erlbeck, and Rodriguez-Lainz, 2014), painted candy wrappers (Kim, Park, Lee, Kim, &et al., 2008), inexpensive children's jewelry (Weidenhamer & Clement, 2007) and toys (Guney & Zagury, 2011; Hillyer, Finch, Cerel, Dattelbaum, & Leopold, 2014; Kumar & Pastore, 2007).

The most common routes of exposure to heavy metals are inhalation and ingestion. Heavy metals are inhaled from contaminated air, household dust, and soil. Ingestion of heavy metals occur in many different ways and may occur from consumption of contaminated foods, juices, and water, eating from heavy metal treated pottery or cookware, by chewing or placing contaminated painted candy wrappers or toys in the mouth. While exposure to heavy metals may be possible through a lesion or opening/break in the skin, ingestion and inhalation places individuals at a greater exposure (Morais, Costa, & Pereira, 2012). Heavy metal exposure can impact people of all ages; but heavy metal exposure has the greatest impact on children's health (Horton, Mortensen, Iossifova, Wald, & Burgess, 2013).

1.2 Heavy Metal Exposure is a Special Danger to Children

There are many factors that explain why children are at special risk for heavy metal exposure. One factor concerns children's behaviors. Children, especially young children, tend to constantly place objects and their hands in their mouths. This "hand to mouth" behavior is recognized as the greatest source of heavy metal exposure in children (ATSDR, 2007a.; Doyle, Blais, & White, 2010). There are two ways in which hand-to-mouth behaviors expose children to heavy metals. Objects may be made from materials that contain a heavy metal. For example, many toys produced in China are known to be painted with lead paint, and inexpensive children's jewelry (Weidenhamer & Clement, 2007) and plastic toys are often made with lead or cadmium (Guney & Zagury, 2011; Hillyer et al., 2014; Kumar & Pastore, 2007). If a child puts any of these objects in their mouths they can absorb heavy metal particles (Guney & Zagury, 2011).

The second way that hand-to-mouth behaviors can expose children to heavy metals is when heavy metal particles are present in contaminated residential soil or air, and in household dust (McDermott et al., 2014). In this case, children's hands can become covered with contaminated soil or contaminated household dust and expose the child to heavy metals when children put unwashed hands into their mouths.

The nutritional habits of children can also influence their exposure and absorption of heavy metals. One reason for this is that, as compared with adults, children can consume larger proportions of foods that can carry heavy metals, including for example vegetables, rice, fruits, juices, and water (Rahbar et.al. 2012; Naujokas et. al., 2013). The more of these that are consumed, the more heavy metals may be ingested. On the other hand, studies have also suggested that when food-intake is irregular and children are not able to eat when they are hungry, heavy metal absorption is greater because the body is looking for nutrients to be absorbed (M. E. Vahter, 2007). Moreover, when children have poor nutrition, they lack essential vitamins, minerals, and proteins that can counteract the absorption of heavy metals (M. Vahter, 2009; M. E. Vahter, 2007). Such essential nutrients that will inhibit heavy metal absorption in children include calcium, zinc, iron, and vitamin C (Bartrem et al., 2013; Bradman, Eskenazi, Sutton, Athanasoulis, & Goldman, 2001; Goyer, 1997; Mahaffey, 1983; Morisson, 1987; Roy et al., 2011). There is another problem that can occur when children are deficient in basic nutrients. Under-nourished children can become anemic and it has been shown that anemia puts children at greater risk for absorbing heavy metals (Landrigan et al., 1976; Liu et al., 2014; Shah et al., 2011).

Another factor is that children's bodies normally absorb a higher percentage of ingested heavy metals than adults. For example, it has been estimated that children absorb forty-percent more lead (Ziegler, Edwards, Jensen, Mahaffey, & Fomon, 1978), and sixty to ninety percent more arsenic than adults (A. H. Hall, 2002; Rodriguez-Barranco et al., 2013; Ziegler et al., 1978).

Another factor that increases children's vulnerability to heavy metal absorption is that children's bodies do not metabolize heavy metals efficiently. A child's body takes many years to fully develop the mechanisms needed to metabolize and eliminate heavy metals (Bartrem et al., 2013; Landrigan, Suk, & Amler, 1999). In young children, when heavy metals are breathed or ingested, as compared with adults, they more quickly accumulate in children's bodies (Bartrem et al., 2013). This has been shown with regard to lead absorption. For example, one process by which absorbed lead is "managed" in the body is by deposition in bone. In children however, because the mechanisms that move lead from blood to bone are not developed, the lead stays in the bloodstream longer and ends up accumulating in kidney, liver, heart, or brain (Healy, Wildfang, Zakharyan, & Aposhian, 1999; Rodriguez-Barranco et al., 2013).

Heavy metals deposited in bone have another effect on children's health. Bones need calcium and other nutrients to grow but if children lack nutrients and are exposed to heavy metals then the bone absorbs heavy metals in place of nutrients. Therefore, heavy metals like cadmium, arsenic, and lead are deposited in bone in place of calcium, weakening bone, and reducing bone growth (Sughis, Penders, Haufroid, Nemery, & Nawrot, 2011; Yang et al., 2013).

In the case of arsenic, it is metabolized in the liver. A young child is not likely to have mature liver pathways needed to metabolize absorbed arsenic, and so will not excrete arsenic through urine efficiently. When arsenic is not excreted through urine, it will circulate and concentrate in the blood system and deposit in other organs (Woolf, Goldman, & Bellinger, 2007). The liver and kidneys are responsible for filtrating and metabolizing foreign substances that enter the body, and if a heavy metal, in this case arsenic, is constantly in the body system, circulating arsenic will put a special burden on these organs that eventually damage them (Healy et al., 1999; Rodriguez-Barranco et al., 2013). The longer heavy metals stay in the body, the risk of damaging other organs increases.

Another reason why children's organs are especially vulnerable to the effects of heavy metals is because their organs are still developing. Accumulated heavy metals that are not eliminated from a child's body can disrupt organ development (Bartrem et al., 2013; Landrigan et al., 1999). With regard to the brain, the blood brain barrier – the layer of densely packed cells within the brain's circulatory system that acts as a protective barrier for the brain – is not fully developed until after the age of about of 36 months and will not block heavy metals from crossing through it (Landrigan et al., 1999). This means of entry to the brain could be partly responsible for the cognitive and behavior abnormalities that have been associated with children who have levels of heavy metals in their body, which will be discussed further below.

1.3.1 Arsenic and Lead Pose Special Risk for Children

Several metals that pose special risk to children have been identified including cadmium, magnesium, mercury, arsenic, and lead (Rodriguez-Barranco et al., 2013). Of these, arsenic and lead may pose the greatest danger to children's mental and physical health because arsenic and lead are the most likely to occur in children's environments, such as in playground and outdoor living areas (Guney, Zagury, Dogan, & Onay, 2010), household dust, and food and water (ASTDR, 2014). Most studies of arsenic and lead exposure in children have focused on the ill-effects of these heavy metals at relatively high levels of exposure. It has also become apparent that even at lowest levels of exposure arsenic and lead alter children's physical health and cognitive and behavior development (ATSDR, 2007a.; Brown & Margolis, 2012). The following sections will describe health effects on children for both high and low exposure to arsenic and lead, with special focus on cognition and behavior, and will describe more why children's environment exposes them to arsenic and lead.

1.3.2 The Dangers of Arsenic

1.3.2.1 Arsenic Causes Damage in Several Organ Systems

Research on the effects of arsenic on the body have focused almost entirely on adults exposed to high levels of this heavy metal, but some effects have been noted in children as well. In children, arsenic is known to damage the lungs and can cause respiratory and pulmonary diseases, including chronic cough, inflammation of the bronchioles and/or lung cancer (Smith et al., 2013). Arsenic also damages the skin, the body's largest organ, by causing skin color change known as arsenicosis, dark spotted areas, rashes and lesions, and disfiguration of the skin (Mazumder, 2007). These physical effects are only examples of what arsenic could cause when arsenic is present at high concentrations in children's body. Whether arsenic causes these conditions and others at lower concentrations and/or when exposure is chronic exposure is not yet known because studies of effects at lower exposure levels in children have not been completed.

1.3.2.2 Arsenic Exposure Affects Brain and Behavior in Children

The effect of early chronic exposure to low-level arsenic has been associated with neurodevelopmental and behavioral disorders. At lower levels of arsenic exposure, the most frequently reported effects, according to two meta-analysis articles on arsenic exposure, are on cognition. Very few studies have examined effects on behavior (Rodriguez-Barranco et al., 2013; Tyler & Allan, 2014).

For example, in studies that measured low (<50μg/L) to medium (51μg/L to 100μg/L) urine concentrations of arsenic exposure, the findings showed lower IQ test scores (Hamadani et al., 2011; Rocha-Amador, Navarro, Carrizales, Morales, & Calderon, 2007; Rosado et al., 2007; von Ehrenstein et al., 2007; S. X. Wang et al., 2007; Wasserman et al., 2004; Wasserman et al., 2011) and a difference of scores between genders, with girls showing greater effects on performance than boys (Hamadani et al., 2011).

Two studies measured blood arsenic levels and showed a decrease in verbal comprehension and working memory among 299 children ages 8-11 years old (Wasserman et al., 2011). Another study showed decreased motor function also among children ages 8-11 years old (Parvez et al., 2011). There has not been a clear relationship between low arsenic exposure and behavioral disorders as suggested by other meta-analyses (Khan et al., 2011; Roy et al., 2011). There is a need for more research on low level arsenic exposure and its possible effects in behavioral disorders in children, especially chronic exposure overtime.

1.3.2.3 Measuring Inorganic Arsenic Absorption in Children

Inorganic arsenic, as compared with organic arsenic, is the form that is dangerous to humans. Many studies have measured child inorganic arsenic exposure by determining concentrations in urine using gas furnace atomic absorption spectrometry (GFAAS) perhaps because this method is convenient. Urine samples are non-invasive; they indicate a relatively recent exposure to arsenic (within the past 24 hours). However, GFAAS is an older technology and can detect only moderate to higher levels of arsenic concentration. Recent studies (Wasserman, 2013) have shown that very low levels of arsenic are also dangerous for children and different methods of detection may be needed. Blood samples can indicate exposure within the past 48 hours (M. Hall et al., 2006) and may have several advantages over urine. It has been pointed out that urine samples reflect excretion, not tissue burden, and are greatly determined by hydration (how often a child urinates) (Barr et al., 2005). Blood samples are a better indicator of tissue burden and accumulated body arsenic in cases of chronic exposure (Klaassen, 2001). Blood collection can be non-invasive when a "finger-stick" blood collection method is used. When analyzed by Inductively Coupled Plasma Mass Spectrometry (ICP-MS), blood samples allow for the detection of arsenic levels at very low concentrations because as compared with GFAAS, the ICP-MS method has much greater precision. Previously it was suggested that blood samples may not demonstrate arsenic exposure because arsenic is very fast at dispersing to other organs rather than staying in the blood, but more recently it has been shown that blood samples are a reliable and valid biomarker of exposure at lowest levels of arsenic exposure (M. Hall et al., 2006; Morton, 1994). Testing for inorganic arsenic exposure can also be done using hair or nail clipping samples and these approaches are useful for determining long-term chronic exposure. However measuring arsenic in these ways indicates cumulative exposure, and cannot indicate if exposure is very recent or current, as these types of samples indicate an exposure greater than 3 weeks.

1.3.3 The Dangers of Lead

1.3.3.1 Lead Causes Damage in Several Organ Systems

Health effects due to lead exposure have been researched far more extensively than arsenic, or practically any other heavy metal. For children, at high levels of exposure (> 25 μg/dL), lead exposure can cause kidney failure, inflammation of the Central Nervous System (CNS), vital organ shutdown, and even death (de Burbure et al., 2006). In recent decades, concerns regarding very low-level exposure in children have increased, since chronic low-level lead exposure has been shown to elevate blood pressure from pre-natal exposure (Zhang et al., 2012), and disrupt puberty in 7-11 years old girls (Gollenberg, Hediger, Lee, Himes, & Louis, 2010). As discussed above, children's bodies are not able to excrete lead as easily as adults. Lead that is not excreted is deposited in bone and can later be released back into the blood system causing anemia (Shah et al., 2011) and/or organ damage (Landrigan et al., 1975; Zhang et al., 2012).

1.3.3.2. Lead Alters Cognition and Behavior in Children

Many studies have shown that even at lowest levels of exposure, lead alters IQ, cognitive function, and behavior in children. In one study of children ages 3 to 5 years of age, whose blood lead concentrations were <10 μg/dL, blood lead was associated with lower IQ scores and exposed children had greater decline in IQ as compared with children who had higher blood lead concentrations (Canfield, 2003). In another study, there was an decrease in Full Scale IQ test scores in children having lead levels between 2 μg/dL and 7 μg/dL (Jusko et al., 2008). Another study showed disruption in cognitive function such as reading, and arithmetic at levels less than 5 μg/dL (Lanphear, Dietrich, Auinger, & Cox, 2000). Low blood lead levels less than 5μg/dL in children ages 4-12 have demonstrated associations in decreasing neurocognition when performing visual neurocognition tests (Sobin et al. 2015). Perhaps most alarming, there is evidence that this early cognitive disruption is carried through adulthood (Mazumdar et al., 2011).

Lead also alters children's behavior by disrupting attention and promoting aggression. Attention Deficit Hyperactivity Disorder (ADHD) is one of the main behavioral disorders associated with low-level lead exposure in children (Kim et al., 2013). In one study of 6 to 9 year old children, children whose mean blood lead levels were 9.02 μg/dL had low scores on the Wechsler Intelligence Scale for Children (WISC-RM) attention test, with no changes noted in IQ test scores (Calderon et al., 2001).

Aggression is the other key behavioral effect observed in people with lead exposure during childhood. For example, one study demonstrated that adults whose childhood blood lead levels were lower than 5 μg/dL had significantly more violent offense arrests (Wright et al., 2008). Though more research is still needed to determine what other behavioral effects may be found in children with low blood lead levels.

1.3.3.3 Measuring Lead Absorption in Children

Lead is the most widely tested heavy metal and is usually tested in whole blood. This method has been proven to be the most efficient way of determining lead exposure (CDC, 2014). Lead can also be measured in hair, teeth and fingernail clippings however these samples cannot determine current or very recent exposure. One study attempted to use urine samples to examine associations between prenatal exposure to low-level arsenic and lead, and cognitive function at 4 years of age in children. In this study blood sample lead levels, but not urine lead sample levels, were associated with cognitive outcomes showing that it is important to use blood samples in studies that test for associations between lead level and cognitive outcome (Forns et al., 2014).

1.4 How Arsenic and Lead Enter the Body

As mentioned, arsenic and lead can enter the body through either ingestion or inhalation. Thus, with regard to water sources of lead and arsenic, children consume these through the gut. Once ingested, arsenic and lead go through different processes.

With regard to arsenic, the metabolic pathway is in the liver. After ingestion, both organic and inorganic forms of arsenic are absorbed into the blood stream from the gastrointestinal track, and the organic form is absorbed by organs (A. H. Hall, 2002). Then the inorganic form is further metabolized in the liver into two arsenic types. The inorganic form of arsenic (arsenate) first changes to arsenite, and then undergoes methylation yielding the two forms monomethylarsonic acid (MMA) and dimethylarsinic acid (DMA). Both organic and inorganic forms are then distributed throughout the body by attaching to a phosphate group and being absorbed in different organs, then eventually are secreted in urine (Hughes, 2002). Up to 48 hours after ingestion, arsenic and its metabolites are circulating in the blood circulatory system and can be measured as total blood arsenic.

Both forms of arsenic, organic and inorganic, can be harmful to humans (Majumdar & Guha Mazumder, 2012). Yet it is the inorganic metabolites, like MMA and DMA, that are believed to be responsible for the effects seen in the brain, and thus probably responsible for cognitive and behavior problems. The effects of arsenic and its metabolites on behavior are not well understood but these metabolites have been found in brain regions such as the hippocampus (Luo, Qiu, Zhang, & Shu, 2012) and affect cellular signaling, cellular growth, alter mitochondria, change DNA structure, and can result in cell death (Naujokas et al., 2013).

Similar to arsenic, lead enters the body through ingestion or inhalation, and affects some of the same as well as different peripheral and neural pathways. After ingestion, inorganic lead is carried by the blood system and absorbed by all organs. Lead has the capacity to spread all over the body because its structural properties mimic calcium, allowing to be carried by different cells and eventually to different organs (Olympio, Goncalves, Gunther, & Bechara, 2009). Its major target is bone, since growing bones require high quantities of calcium. Bones become the number one place in which lead is deposited. Lead deposit in bone can be harmful since, as discussed above, it will weaken bone matrix. When bone fractures occur, stored lead will release into the body as the body goes into a state of high bone turnover for repair, increasing blood lead level and spreading to other vulnerable organs.

1. 5 Drinking Water as a Source of Arsenic and Lead Exposure in Children

1.5.1 Arsenic in Drinking Water

Arsenic is naturally found in the soil, and in air. It is part of the earth's crust composition, and can be easily carried by wind. Water becomes contaminated with arsenic because it comes in contact with contaminated soil or contaminated waste, and leaches arsenic into drinking water sources.

Because of its daily use for many reasons including drinking, food preparation, bathing, face washing, teeth-brushing and hand-washing, contaminated drinking water can be a major source for arsenic exposure in children. It has been suggested that children who consume water that exceeds the WHO and EPA maximum contaminant level for arsenic in water (10 μg/L) are likely to have elevated blood or urine arsenic levels based on the referenced studies (Rocha-Amador et al., 2007; Tsai, Chou, The, Chen, & Chen, 2003; von Ehrenstein et al., 2007; Wasserman et al., 2007; Wasserman et al., 2004). Even in children who consumed household water below the EPA arsenic standard had low arsenic concentrations of 0.48 μg/dL (Wasserman 2011; Parvez et al., 2011). Both high and low arsenic water levels have been associated with exposure to arsenic in children, and consequently contributing to the health effects that are caused at these levels (Parvez et al., 2011; Rocha-Amador et al., 2007; Tsai et al., 2003; von Ehrenstein et al., 2007; S. X. Wang et al., 2007; Wasserman et al., 2007; Wasserman et al., 2004; Wasserman et al., 2011).

It is more likely that domestic well water sources have elevated concentrations of arsenic compared to sources from municipal systems because municipal systems are regulated and treated to <10 µg/L while domestic wells are not treated for arsenic (Rocha-Amador et al., 2007).

1.5.2 Lead in Drinking Water

In the United States, the major sources of child exposure to lead are lead paint, lead-contaminated household dust, and lead-contaminated soil (Levin, 2008). Lead may also be present in household tap water in at-risk communities located near industrial sites that produce lead-contaminated emissions, or in homes with lead pipes and lead fixtures. Studies have shown associations between lead levels of household tap water and blood lead levels in children (Brown, Raymond, Homa, Kennedy, & Sinks, 2011; Cosgrove et al., 1989; Edwards, Triantafyllidou, & Best, 2009; Guidotti et al., 2007; Shannon & Graef, 1989). In a previous study, lead levels in household tap water were a risk indicator for lead exposure in children, whose blood levels were 5-9 µg/dL or greater than 10 µg/dL (Brown et al., 2011).

Lead levels in household tap water are most commonly due to lead plumbing. Lead from pipes can leach into the household tap water. Homes built before 1980's are most likely to have leaded service lines with leaded pipes and fixtures or copper pipes with lead-soldered joints. Homes built after 1986 may have partially leaded service lines, or have "lead-free" plumbing that still contain 8% lead (Brown et al., 2011; Payne, 2008; "SDWA," 1986; Schock, 1996). The corrosion of any of these plumbing materials can leach lead into drinking water. Factors that create corrosion of these plumbing materials include increased water pH levels, and type of source water treatment (Brown et al., 2011; Moore, Goldberg, Fyfe, & Richards, 1981).

1.6 Children in Two Rural Communities in the Southwest US are at Risk for Arsenic and Lead Exposure

In the southwest United States, water is a special source of concern for arsenic and lead exposure in children, whether the source is from a public municipal system or private well source (Anning , McKinney, Huntington, Bexfield, & Thiros, 2012). Arsenic contaminated water from private wells with levels above the Environmental Protection Agency (EPA) acceptable limit (10 µg/L, Maximum Contaminant Level, MCL) have been reported in the United States (Naujokas et al., 2013). In some areas of the U.S.-Mexico border region, domestic or privately owned publicly available drinking water systems may not be regulated or monitored for heavy metals like municipal public water systems. This is especially true in areas designated as "colonias" – that is, unincorporated areas in which families live in houses and communities lacking in infrastructure.

In a recent study of the groundwater in the two rural communities of interest, it was shown that some of the water samples collected had arsenic levels above the EPA MCL (Hargrove, et al., 2015). Whether or not arsenic in the home tap water is associated with arsenic blood levels in children has not yet been examined.

It is also not known whether arsenic in the source groundwater may impact absorption of other heavy metals, such as lead (Bartrem et al., 2013) in these children. If two metals such as arsenic and lead occur in equal amounts, relatively equal amounts may be absorbed. However, it is not the case for arsenic and lead. When either arsenic or lead occurs at a higher exposure, the other heavy metal absorption is reduced, but this does not eliminate co-exposure (Bae, Gennings, Carter, Yang, & Campain, 2001; Bartrem et al., 2013; Chiang et al., 2008). The co-exposure can be worrisome. This co-exposure has unique health effects including disruption of hormones; changes in brain function; learning disabilities; and changes in neurobehavior (Bartrem et al., 2013).

Children living in regions where the arsenic levels of home tap water samples have been shown to exceed EPA acceptable standards (Hargrove et al., 2015) require health screening to determine their blood arsenic levels, blood lead levels, and possible effects on other health outcomes including height, weight and body mass index and blood pressure, as well as child behavior. It is also important to determine whether arsenic and lead in the home water sample predicts child blood levels of arsenic and lead.

1.7 Goals of the Study

The goals of the study were to: 1) determine the blood levels of arsenic and lead in children living in two rural communities in the El Paso border region; 2) determine whether arsenic and lead levels in home water samples predict child arsenic and lead blood levels; and 3) determine whether blood levels of arsenic and/or lead predict behavior (Strengths and Difficulties Questionnaire scores).

1.8 Hypotheses

Goal 1 (see above) is descriptive and does not require hypotheses. Three hypotheses are proposed that support Goal 2 and Goal 3. Goal 2, H1): there is a linear relationship between arsenic in home water samples and child blood arsenic levels; Goal 2, H2): there is a linear relationship between lead in home water samples and child blood lead levels. Goal3, H3): there is a linear relationship between child (heavy metal) level and the summary score from the child "Strengths and Difficulties Questionnaire." The specific hypotheses to address Goal 3 will depend on the levels of lead and/or arsenic found in child blood samples. If detectable levels of both heavy metals are found, hypotheses regarding behavior outcomes will be tested for each heavy metal. If significant levels of only arsenic or only lead are found, the hypotheses will be tested only for that heavy metal. With regard to behavioral outcomes, additional secondary analyses will be conducted depending on the results of the primary analyses. For example, if no association between the heavy metal exposure and the SDQ summary score is found, additional analyses will explore whether associations exist between heavy metal blood levels and SDQ subscales (emotional symptoms, conduct problems, hyperactivity, peer social problems; and prosocial behavior).

1.9 Aims and Objectives

There were three outreach objectives associated with this study. These were to: 1) educate the public about arsenic and lead health exposures in children's development; 2) provide a service to the community by providing free blood arsenic and lead testing for potentially vulnerable children; 3) determine whether children living in two rural areas at high-risk for water borne arsenic and lead, have elevated arsenic and/or lead blood levels.

Methods and Materials

2.1 Demographic Summary of the Communities Sampled

Two communities located northwest of El Paso, Texas and approximately 20 miles from the US-Mexico Border port of entry were sampled for this study. To protect the confidentiality and anonymity of the study participants, the communities will be referred to as Community 1 and Community 2. Community 1 is a peri-urban community with 1,971 residents and 536 households ("American Fact Finder," 2010). The community is predominantly of Hispanic or Latino descent (94.4%), and there are approximately 750 children residing in Community 1, 0-19 years of age ("American Fact Finder," 2010), 181 of whom are between the ages of 5 and 9 (the target age group for this study). Community 1 relies on three different types of water supplies, domestic wells (20%), privately owned public water supply (63%), and municipal public water supply (17%) (Hargrove et al., 2015). Community 2 is a "colonia" and an unincorporated municipality adjacent to Community 1. Community 2 has 4,188 residents and 1,165 households ("American Fact Finder," 2010). It is also populated with residents identified as 97.3% Hispanic or Latino. There are approximately 1,541 children residing in Community 2 ages 0-19 years of age ("American Fact Finder," 2010), 353 of whom are between the ages of 5 and 9 years. Community 2 relies on the municipal public water supply. Parents and children from one elementary school from each these communities were recruited for this study.

2.2 Study Participants

Child participants were identified for participation through parent recruitment at one elementary school from each town during parent teacher night conferences. Permission to recruit parents during parent-teacher conference events were obtained in joint meetings with the Mayor of Community 1, superintendent of the school district, the school board, and the principals and school nurses. The target age range was children 5 to 9 years and currently enrolled at either of the two elementary schools. All testing took place during the school day. Participating children were brought to the participation room during their Physical Education class time.

Parents and children were compensated for their participation in the study with a 5-dollar gift card to a retail store after they completed each phase of the study (initial recruitment and form completion, child testing, and water sample collection). All study forms and materials were available in Spanish and English versions. Researchers on this study were bilingual and throughout the study interacted with participants in the participant's preferred language.

2.3 Sample Size

This was a pilot study and recruitment was conducted with the goal of enrolling as many children as possible. Very few past studies have examined associations between environmental contamination (i.e., arsenic in water) and child blood arsenic and lead levels, or between child blood arsenic and lead levels and behavior, and effect sizes could not be anticipated (for the purpose of a power analysis). That being said, we aimed for a minimum of 50 children from each site with the goal of achieving a pilot sample of at least 100 children total, which would represent approximately 10% of the total number of children in both schools.

2.4 Study Design

This was an observational study of Hispanic children living in two rural towns in El Paso County within 20 miles of the U.S.-Mexico border. The children were a convenience sample and observations were cross-sectional (that is, individual samples collected at one point in time). The results reported here was part of a larger project, which included the collection of other data, not analyzed in this report.

2.5 Institutional Review Board

Institutional Review Board (IRB) approval was obtained prior to data collection (IRB Protocol # 564493-2). Informed consent to participate was obtained from parents prior to the study and assent from each child was obtained immediately prior to testing. All individuals working on or volunteering to help on this study completed required human subjects training, and for handling blood samples, conducting parent interviews, de-identifying health information, and maintaining participant confidentiality in this study. Standard operating procedures were written for all steps of the study procedures, including step-by-step methods for blood collection, water sample collection, and data entry.

2.6 Blood Samples

Blood samples were collected during the first two weeks of April 2014, during the physical education class times. One finger stick whole blood sample of 50 microliters from each child was collected into a sterile EDTA micro-vial via capillary tubes. Samples remained at room temperature for about 1-3 hours, and were later stored at 4°C, until they were transported on ice to the laboratory for analysis. The samples were tested for heavy metal levels of lead, cadmium, and arsenic, and iron in whole blood. Blood samples were analyzed using Inductive-Coupled Plasma Mass Spectrometry (ICP-MS) (Bazzi, Nriagu, & Linder, 2008) analysis conducted by the chemistry laboratory at New Mexico State University, Las Cruces (Tanner Schuab, PhD, laboratory head). Heavy metal blood levels were recorded as continuous variables in micrograms per deciliter (μg/dL).

2.7 Home Water Samples

Household water samples were collected during the first two weeks of June 2014 by the study team following the “Quick Guide to Drinking Water Sample Collection” from the US Environmental Protection Agency, 2005. Appointments were scheduled with parents who had provided prior consent for the home procedure. On the day of water collection, a two-member research team collected the water sample from the kitchen faucet and completed a household survey about water use practices and the source of the household water. The water sampling procedure consisted of identifying the kitchen faucet; removing filters from the mouth of the faucet, cleaning the mouth of the faucet with 70% alcohol and lint-free wipes, and allowing ambient temperature water run for 5 seconds. A water sample was then collected in a beaker and the pH and temperature of water were tested using portable electronic pH meters (Thermo-Scientific Orion 5-Star, Fisher Scientific, Waltham, MA), and recorded. After the pH test, about 250mL of the water sample was collected in screw top plastic container treated with 2% nitric acid (bottles were provided by analyzing laboratory). After collection, the household water sample was labeled with the household study ID and stored at 4C° using wet ice. Following collection, water samples were kept overnight at 4C° and transported the following day to the analyzing laboratory. Home water samples were analyzed by ICP-MS for heavy metals arsenic, lead, cadmium, and mercury in μg/dL (Alamo Analytical Laboratories, San Antonio, TX).

The household water use survey (Appendix A) consisted of 19 questions that asked for the number of children in the household, drinking water source, household water source, and water consumption patterns for parent and child, subjective evaluation of the quality of drinking water, and brief household history of possible gastrointestinal diseases over the past 6 months.

Household water from Community 1 was from domestic wells, or from privately owned wells made available to the public for a fee. Household water from Community 2 was from the municipal public water supply. “Domestic wells” refers to a single well on household property and usually serves one household. Privately owned wells made available to the public for a fee are local wells that provide at least 15 connections, or serve a minimum of 25 individuals. The municipal public water supply provides connections for any households in the service area.

2.8 Behavioral Assessment

Child behavior was assessed using the child “Strengths and Difficulties Questionnaire” (Goodman & Goodman, 2012) (Appendix B). The questionnaire has been determined to be a reliable screening tool for behavioral assessment of the child through parent interview. (This form does not provide psychiatric diagnoses but provides valid and reliable screening for negative and positive child behavior patterns). The questionnaire has twenty-eight questions and assesses child difficulties including emotional symptoms, conduct problems, hyperactivity, and peer social problems, and child strengths including prosocial behavior. Parents completed the questionnaire during recruitment after the signing of consent forms (during February and March of 2014), and specially trained student workers were always present to answer parents’ questions and ensure proper completion of the forms. Scores were generated from these forms based on the standard scoring scale (Goodman & Goodman, 2012).

2. 9 Health Assessment

A brief health assessment survey of the child was completed by the parent (Appendix C) also during parent recruitment phase. This form asked basic demographic, socio-economic, and brief medical behavior history of child, along with any history of heavy metal testing, and questions regarding behavioral or learning disabilities, and health conditions. The questionnaire consisted of twenty questions and was completed by parents at the time of recruitment following informed consent and a member of the research team was always available to answer parents' questions regarding the form.

2.10 Data Analysis Plan

Prior to statistical analysis, all data and data distributions were examined. Children's home tap water was characterized with regard to levels of arsenic and lead; and children were characterized with regard to blood levels of arsenic, and lead, and behavior (based on parent report on SDQ). For cross-sectional analyses, generalized mixed model linear regression analyses were used to examine associations between home tap water arsenic levels, children's contaminant blood levels, and behavior controlling for school (random effect).

Results

There were 123 participants recruited for the study. Two children dropped from school before blood collection, one child declined blood drawing, and two children were absent during the days of blood collection. Out of the remaining 118 participants, there were fourteen participants who were not included in the analysis because they had missing data either from blood and/or water analysis, and/or parents did not complete the behavior assessment, leaving a total of 104 participants in the study to be analyzed.

Out of 84 possible homes, 72 home water samples were collected, 32 homes from Community 1 and 40 homes from Community 2. Two participant's home samples were collected from next-door neighbors because they were not available to provide water samples from their homes. One family refused to allow water collection, and ten families could not be reached to schedule the water sample collection.

Table 1 shows the demographic characteristics of the analyzed sample of 104 children, including 57 (54.8%) males (mean age 7.85±1.81 years) and 47 (45.2%) females (mean age 8.11 ±1.95 years, age range 4.24-12.3 years of age). All of the mothers self-identified as Hispanic (60.58%), Latino (5.77%), Mexican American (9.62%), or Mexican (24.04%). The families in this study had a mean annual household income of $20,281.86 (± $15,480.09) with a range of $0-$75,000 (one outlier value of $144,000 was not included in the mean calculation). The mean family size was 5.26 (±1.44). The U.S. national poverty threshold for 2014 was $29,447 for a family size of five, for homes with children under the age of eighteen; seventy-five percent of families in the study fell below the poverty threshold (US Census, 2014).

Body Mass Index (BMI) was calculated according to a child's gender and age. The mean BMI for females (17.77±3.93) and males (17.61±4.23) based on a mean age of 7.97±1.87 was within the U.S. range (fifth to eighty-fifth percentile) of “healthy” to borderline “overweight” BMI for females (13.5-18.3) and males (13.8-18.0) (Dinsdale, Ridler, & Ells, 2011; Kuczmarski, Ogden, & Guo, 2002). For male children, the mean height of 50.05±4.93 inches was at the forty-one percentile of the national average, and the mean weight of 65.10±26.65 pounds was at eightieth percentile of boys eight years of age (Kuczmarski, et. al, 2002). For female children, the mean height of 50.18±5.42 was at forty-one percentile of the national average, and the mean weight of 66.31±27.24 is at eighty-one percentile of girls eight years of age (Kuczmarski, et. al, 2002). For boys, the mean systolic pressure of 105.05±12.77 was at the seventieth percentile of the national average, and the mean diastolic pressure of 60.75±9.37 is at the fiftieth percentile of boys eight years of age with fiftieth percentile height (U.S. Department of Health and Human Services, 2005). For girls, the mean systolic pressure of 107.74±13.15 was at the eightieth percentile of the national average, and the mean diastolic pressure of 62.98±8.99 is at seventieth percentile of girls eight years of age with fiftieth percentile height (U.S. Department of Health and Human Services, 2005).

The mean values of arsenic blood levels for males and females exceeded the 1.2µg/dL allowable limit in children (See Table 1) (Hall et al., 2006, Mayo Clinic, 2015). When separated by school (Table 2) the blood As values of children from both schools also exceeded the allowable limit. There were more female participants in School 1, yet means for age, weight, height, waist to hip ratio, and BMI of children from the two schools were similar (Table 2) as were systolic and diastolic blood pressures. Mean blood Pb levels from both schools were low; eighty-seven percent of children had blood lead levels below 2.0 µg/dL; the remaining thirteen percent had blood lead levels between 2.11 and 5.29 µg/dL.

There were some observational differences between schools on blood As and Fe levels. A two by two factorial ANOVA design for two levels (school and sex) determined As levels to be significantly different between schools ($F_{1/100}$= 6.44, p= 0.01), with School 1 having higher values than School 2, but there was no further significant differences by sex ($F_{1/100}$= 0.00, p= 0.95), or for the interaction of school by sex ($F_{1/100}$= 0.00, p= 0.95). A two by two factorial ANOVA design for two levels (school and sex) determined Fe levels to be significantly different between schools ($F_{1/100}$= 4.60, p= 0.03) with School 1 having higher values than School 2; there was no difference by sex ($F_{1/100}$= 2.10, p= 0.15) and no significant interaction of school by sex ($F_{1/100}$= 0.08, p= 0.78).

Possible differences in mean values for pH and household water As levels between schools were also apparent (Table 2). One-way ANOVA examining differences between homes from each school for home water pH level and home water As level was calculated. pH levels were significantly different between schools ($F_{1/100}$= 82.31, p= <0.01); home tap water samples of children from School 1 had significantly higher pH levels as compared with home tap water samples of children from School 2. As levels were also significantly different between schools ($F_{1/100}$= 27.22, p= <0.01); homes of children from School 1 had significantly higher As levels as compared to homes of children from School 2. Also, 6/72 (8%) households exceeded the EPA's maximum contaminant level (MCL) for As of 1µg/dL (highest level of1.6 µg/dL), and those exceeding the MCL were in Community 1 (homes of children from School 1). Mean Pb household levels from both communities were not detectable for 71/72 households; Pb levels detected ranged from 0 – 0.10 µg/dL and all were below the MCL for Pb 1.5 µg/dL (U.S. EPA, 2015).

Table 3 shows the means (SD) and range for each of the Strengths and Difficulties Questionnaire categories by school and then by gender.

Table 4 summarizes the Type III fixed effects solutions and parameter estimates for the main effects of blood As and household As water, the interactions of age and sex, controlling for school as random effect. Child blood As level was marginally predicted by household water sample As level ($F_{1/98} = 3.33$, $p= 0.07$). In this model the main effects of age ($F_{1/98} = 0.71$, $p = 0.40$) and sex ($F_{1/98} = 0$, $p = 0.99$.) were not significant, and the interaction of age by sex was also not significant ($F_{1/98} = 0$, $p = 0.10$). The non-significant effects were dropped from the model and the model was re-calculated predicting child blood As level from only household water sample As level. In the reduced model, household water As level was a significant predictor of child blood As level ($F_{1/101} = 4.71$, $p = 0.03$). As shown in Table 4, for every 1 unit increase of household water As, child blood As increases by 0.26 μg/dL.

Associations between household water sample Pb levels and child blood Pb levels were not analyzed because household water Pb levels were not detectable in a majority of samples tested.

Table 5 summarizes the Type III fixed effects solutions and parameter estimates for the model predicting the influence of child blood As levels on child behavior as rated by parents using the Strengths and Difficulties Questionnaire (SDQ). This model included sex, age, and the interaction of sex by age, with school as a random effect. Child As blood level as a main effect was not a predictor of any of the behaviors examined; sex, age and sex by age were also not significant contributors to any of the behavioral outcomes measured.

Table 6 summarizes the Type III fixed effects solutions and parameter estimates for the model predicting the influence of child blood Pb levels on child behavior as rated by parents using the SDQ. This model included sex, age, and the interaction of sex by age, with school as a random effect. Child Pb level as a main effect was not a predictor of any of the behaviors examined; sex, age, and sex by age were also not significant contributors to any for any of the behavioral outcomes measured.

Table 1

Clinical and Demographic Characteristics of Male and Female Children

Variable	Male (n=57) (54.8%)	Females (n=47) (45.2%)	Total (N=104)
School 1	27 (67.5%)	13 (32.5%)	40
School 2	30 (46.9%)	34 (53.1%)	64
Age (SD)	7.85 (±1.81)	8.11 (±1.95)	7.97 (±1.87)
Weight[a] lbs. (SD)	65.10 (±26.65)	66.31 (±27.24)	65.64 (±26.80)
Height[a] in. (SD)	50.05 (±4.93)	50.18 (±5.42)	50.11 (±5.13)
W/H Ratio[a] (SD)	0.88 (±0.06)	0.89 (±0.17)	0.88 (±0.12)
BMI[a] (SD)	17.61 (±4.23)	17.77 (±3.93)	17.68 (±4.10)
SYS BP (SD)	105.05 (±12.77)	107.74 (±13.15)	106.27 (±12.95)
DIA BP (SD)	60.75 (±9.37)	62.98 (±8.99)	61.76 (±9.22)
As µg/dL (SD)	1.31 (±0.45)	1.27 (±0.39)	1.29 (±0.42)
Pb µg/dL (SD)	1.19 (±1.20)	1.03 (±0.88)	1.12 (±1.07)
Hispanic	34/57 (59.6%)	29/47 (61.7%)	63/104 (60.58%)
Latino	3/57 (5.26%)	3/47 (6.38%)	6/104 (5.77%)
Mexican American	8/57 (14.04%)	2/47 (4.26%)	10/104 (9.62%)
Mexican	12/57 (21.05%)	13/47 (28.77%)	25/104 (24.04%)
Household Income[b]	24136.64 (±23309.71)	18187.55 (±13538.30)	21519.04 (±19755.37)
Family Size	5.21 (±1.46)	5.32 (±1.43)	5.26 (±1.44)

[a] n=103, one student was in a wheelchair.

[b] males n=56; females n=46 (range=0-144000)

Table 2

Clinical and Water Levels by School and Sex

	School 1			School 2		
	Male	Female	Total	Male	Female	Total
Variable	(n=27) (67.5%)	(n=13) (32.5%)	(n=40)	(n=30) (46.9%)	(n=34) (53.1%)	(n=64)
Age (SD)	7.94 (±1.76)	8.10 (±1.91)	7.97 (±1.79)	7.77 (±1.88)	8.13 (±1.99)	7.96 (±1.93)
Weight[a] lbs. (SD)	65.76 (±27.09)	66.80 (±23.83)	66.10 (±25.77)	64.43 (±26.70)	66.12 (±28.76)	65.35 (±27.62)
Height[a] in. (SD)	50.03 (±5.07)	50.25 (±5.85)	50.11 (±5.26)	50.05 (±4.89)	50.15 (±5.34)	50.11 (±5.10)
W/H Ratio[a] (SD)	0.88 (±0.06)	0.90 (±0.05)	0.89 (±0.06)	0.87 (±0.06)	0.89 (±0.20)	0.88 (±0.15)
BMI[a] (SD)	17.80 (±4.11)	17.99 (±3.95)	17.86 (±4.01)	17.43 (±4.40)	17.69 (±3.98)	17.57 (±4.15)
SYS (SD)	101.30 (±10.02)	101.00 (±9.13)	101.20 (±9.62)	108.43 (±14.13)	110.32 (±13.64)	109.44 (±13.79)
DIA (SD)	58.37 (±8.64)	61.15 (±5.63)	59.27 (±7.83)	62.90 (±9.62)	63.68 (±9.96)	63.31 (±9.73)
As BL μg/dL (SD)	1.43 (±0.43)	1.43 (±0.35)	1.43 (±0.41)	1.20 (±0.45)	1.21 (±0.39)	1.20 (±0.42)
Pb BL μg/dL (SD)	1.25 (± 1.47)	0.93 (±0.94)	1.15 (±1.32)	1.13 (±0.91)	1.07 (±0.87)	1.10 (±0.88)
Fe BL μg/dL (SD)	12125.04 (±3278.48)	11235.31 (±833.04)	11835.88 (±2749.05)	10878.69 (±2268.22)	10279.55 (2197.80)	10560.40 (±2233.66)
H_2O pH (SD)	7.76 (±0.39)	7.83 (±0.39)	7.78 (±0.39)	7.29 (±0.11)	7.27 (±0.18)	7.28 (±0.15)
H_2O As μg/dL (SD)	0.65 (±0.39)	0.84 (±0.15)	0.71 (±0.34)	0.43 (±0.31)	0.31 (±0.32)	0.37 (±0.32)
H_2O Pb μg/dL (SD)	0	0.01 (±0.03)	0.003 (±0.02)	0	0	0
Family Size	5.15 (±1.29)	5.00 (±1.22)	5.10 (±1.26)	5.27 (±1.62)	5.44 (±1.50)	5.36 (±1.55)
Household Income[b]	23744.00 (±1896.50)[1]	21518.18 (±14446.09)[2]	23063.89 (±17528.48)[3]	20468.40 (±14948.36)[4]	17077.33 (±13266.13)[5]	18692.13 (±14080.73)[6]

[a] n=103 one child in wheel chair

[b] n=100; [1] n=25 (range=0-75000) with outlier value of $144,000; [2] n=11 (range=10000-40000); [3] n=37 ; [4] n=30 (range=0-54000); [5] n=33 (range=880-53120); [6] n=63

Table 3 *Descriptive Statistics for Behavioral Assessment by School and Sex*

	School 1					
	Male		Female		Total	
Category	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range
Emotional Problems[a]	2.52 ± 2.74	0-9	2.54 ± 2.18	0-6	2.53 ± 2.55	0-9
Conduct Problems[a]	1.70 ± 1.41	0-5	1.31 ± 1.25	0-4	1.58 ± 1.36	0-5
Hyperactivity[a]	4.85 ± 2.76	0-10	3.65 ± 2.32	0-8	4.46 ± 2.65	0-10
Peer Relationship Problems[a]	2.07 ± 1.62	0-6	2.77 ± 1.59	0-6	2.30 ± 1.62	0-6
Total Difficulties[b]	11.15 ± 6.63	2-25	10.27 ± 5.39	0-19	10.86 ± 6.19	0-25
Prosocial Behavior[a]	7.89 ± 2.34	1-10	7.92 ±2.02	4-10	7.90 ± 2.22	1-10
	School 2					
	Male		Female		Total	
	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range
Emotional Problems[a]	2.28 ± 2.39	0-8	1.82 ± 1.75	0-6	2.03 ± 2.07	0-8
Conduct Problems[a]	1.33 ± 1.30	0-6	1.65 ± 1.37	0-4	1.50 ± 1.33	0-6
Hyperactivity[a]	3.77 ± 2.21	0-9	2.99 ± 2.47	0-8	3.36 ± 2.37	0-9
Peer Relationship Problems[a]	2.32 ± 1.78	0-7	2.65 ± 2.07	0-8	2.50 ± 1.93	0-8
Total Difficulties[b]	9.69 ± 5.61	0-22	9.11 ± 5.68	0-18	9.39 ± 5.61	0-22
Prosocial Behavior[a]	8.45 ± 2.06	0-10	7.60 ± 2.66	0-10	8.00 ± 2.42	0-10

[a] Out of 10 possible points for each category

[b] Out of 40 possible points

Table 4

Type III Fixed Effects and Parameter Estimates for Associations between As Level in Household Water and Child As Blood Levels, Controlling for Sex, Age, and School (random effect)

Type III fixed effect				*Solutions for fixed effects*					
	F	*p*			Est	SE	DF	t value	*p*
Full Model				*Intercept*	2.10	0.68	98.00	3.11	<0.01
H_2O As	3.33	**0.07**		H_2O As	0.23	0.12	98.00	1.83	**0.07**
Age	0.71	0.40		Age	-0.02	0.03	98.00	-0.61	0.54
Sex	0.00	0.99		Sex Male	- <0.01	0.33	98.00	-0.01	0.99
Age *x* Sex	0.00	1.00		Sex Female	0.00	-	-	-	-
				Age *x* Sex Male	- <0.01	0.04	98.00	- 0.00	1.00
				Age *x* Sex Female	0.00	-	-	-	-
Reduced Model				*Intercept*	1.83	0.57	101.00	3.20	<0.01
H_2O As	4.71	**0.03**		H_2O As	**0.26**	0.12	101.00	2.17	**0.03**

Table 5

Type III Fixed Effects and Parameters Estimates for Associations between Child Blood As Levels and Child Behaviors as Rated on the Strengths and Difficulties Questionnaire (SDQ) controlling for Sex, Age, and School (random effect)

Type III fixed effect				*Solutions for fixed effects*					
	F	*p*			Est	SE	DF	t value	*p*
Total Symptoms				*Intercept*	3.03	0.52	98.00	5.79	<0.01
As	0.00	0.99		As	- < 0.01	0.08	98.00	-0.01	0.99
Age	1.33	0.25		Age	<0.01	0.02	98.00	0.26	0.80
Sex	3.10	0.08		Sex Male	0.45	0.25	98.00	1.76	0.08
Age *x* Sex	2.34	0.13		Sex Female	0.00	-	-	-	-
				Age *x* Sex Male	-0.05	0.03	98.00	-1.53	1.13
				Age *x* Sex Female	0.00	-	-	-	-
Emotional Problems				*Intercept*	0.39	0.57	98.00	0.69	0.49
As	0.61	0.44		As	-0.16	0.20	98.00	-0.78	0.44
Age	0.23	0.63		Age	0.01	0.06	98.00	0.17	0.87
Sex	0.72	0.40		Sex Male	0.57	0.67	98.00	0.85	0.40
Age *x* Sex	0.53	0.47		Sex Female	0.00	-	-	-	-
				Age *x* Sex Male	-0.06	0.09	98.00	-0.72	0.47
				Age *x* Sex Female	0.00	-	-	-	-
Hyperactivity				*Intercept*	1.17	0.91	98.00	1.29	0.20
As	0.02	0.88		As	0.03	0.19	98.00	0.15	0.88
Age	1.53	0.22		Age	-0.08	0.06	98.00	-1.20	0.23
Sex	0.06	0.80		Sex Male	-0.16	0.66	98.00	-0.25	0.80
Age *x* Sex	0.28	0.60		Sex Female	0.00	-	-	-	-
				Age *x* Sex Male	0.05	0.09	98.00	0.53	0.60
				Age *x* Sex Female	0.00	-	-	-	-

Table 5 (Continued)

Type III fixed effect			*Solutions for fixed effects*					
	F	*p*		Est	SE	DF	t value	*p*
Peer Relationship Problems			*Intercept*	0.11	0.51	98.00	0.21	0.83
As	0.00	0.99	As	<0.01	0.18	98.00	0.01	0.99
Age	0.33	0.57	Age	0.06	0.05	98.00	1.09	0.28
Sex	0.53	0.47	Sex Male	0.45	0.62	98.00	0.73	0.47
Age *x* Sex	0.83	0.37	Sex Female	0.00	-	-	-	-
			Age *x* Sex Male	-0.07	0.08	98.00	-0.91	0.37
			Age *x* Sex Female	0.00	-	-	-	-
Conduct Problems			*Intercept*	0.32	0.57	98.00	0.57	0.57
As	0.09	0.76	As	-0.06	0.21	98.00	-0.30	0.76
Age	0.58	0.45	Age	<0.01	0.06	98.00	0.13	0.89
Sex	0.68	0.41	Sex Male	0.57	0.69	98.00	0.82	0.41
Age *x* Sex	0.90	0.35	Sex Female	0.00	-	-	-	-
			Age *x* Sex Male	-0.09	0.09	98.00	-0.95	0.34
			Age *x* Sex Female	0.00	-	-	-	-
Prosocial Behavior			*Intercept*	-0.16	0.60	98.00	-0.27	0.79
As	0.1	0.75	As	0.07	0.21	98.00	0.32	0.75
Age	0.29	0.59	Age	0.04	0.06	98.00	0.65	0.52
Sex	0.05	0.82	Sex Male	0.17	0.73	98.00	0.23	0.82
Age *x* Sex	0.12	0.72	Sex Female	0.00	-	-	-	-
			Age *x* Sex Male	-0.03	0.09	98.00	-0.35	0.72
			Age *x* Sex Female	0.00	-	-	-	-

Table 6

Type III Fixed Effects and Parameters Estimates for Associations between Child Blood Pb Levels and Child Behaviors as Rated on the Strengths and Difficulties Questionnaire (SDQ) Controlling for Sex, Age, and School (random effect)

Type III fixed effect				*Solutions for fixed effects*					
	F	*p*			Est	SE	DF	t value	*p*
Total Symptoms				*Intercept*	3.17	0.46	99.00	6.89	<0.01
Pb	0.09	0.77		Pb	0.01	0.03	99.00	0.30	0.77
Age	1.32	0.25		Age	-0.02	0.02	99.00	-1.15	0.25
Sex	1.21	0.27		Sex Male	0.07	0.06	99.00	1.10	0.27
				Sex Female	0.00	-	-	-	-
Emotional Problems				*Intercept*	0.43	0.37	99.00	1.16	0.25
Pb	0.02	0.88		Pb	-0.01	0.08	99.00	-0.15	0.88
Age	0.18	0.67		Age	-0.02	0.04	99.00	-0.43	0.67
Sex	0.33	0.57		Sex Male	0.10	0.17	99.00	0.58	0.57
				Sex Female	0.00	-	-	-	-
Hyperactivity				*Intercept*	1.14	0.81	99.00	1.42	0.16
Pb	0.11	0.74		Pb	-0.03	0.08	99.00	-0.33	0.74
Age	1.59	0.21		Age	-0.06	0.04	99.00	-1.26	0.21
Sex	1.04	0.31		Sex Male	0.17	0.17	99.00	1.02	0.31
				Sex Female	0.00	-	-	-	-

Table 6 (Continued)

Type III fixed effect				*Solutions for fixed effects*					
	F	*p*			Est	SE	DF	t value	*p*
Peer Relationship Problem				*Intercept*	0.41	0.34	99.00	1.18	0.24
Pb	0.00	0.99		Pb	-0.02	0.07	99.00	-0.27	0.79
Age	0.33	0.57		Age	0.02	0.04	99.00	0.60	0.55
Sex	0.53	0.47		Sex Male	-0.09	0.15	99.00	-0.61	0.55
				Sex Female	0.00	-	-	-	-
Conduct Problems				*Intercept*	0.46	0.38	99.00	1.22	0.22
Pb	0.35	0.56		Pb	0.05	0.08	99.00	0.59	0.56
Age	0.36	0.55		Age	<0.03	0.05	99.00	-0.60	0.55
Sex	0.18	0.67		Sex Male	-0.07	0.17	99.00	-0.43	0.67
				Sex Female	0.00	-	-	-	-
Prosocial Behavior				*Intercept*	0.04	0.40	99.00	0.11	0.91
Pb	0.01	0.91		Pb	0.01	0.08	99.00	0.11	0.91
Age	0.29	0.59		Age	0.03	0.05	99.00	0.54	0.59
Sex	0.20	0.66		Sex Male	-0.08	0.18	99.00	-0.44	0.66
				Sex Female	0.00	-	-	-	-

Discussion

4.1 Study Rationale

This study follows on the results of a Health Impact Assessment (HIA) conducted in two communities along the U.S.-Mexico border back in 2013 (Hargrove et al., 2015). These two geographically adjacent communities had very similar demographic profiles. Both communities were of Hispanic/Mexican origin, and seventy-five percent of families in both communities were living below the U.S. poverty threshold. The communities were distinct in that Community 1 relied mostly (83%) on local wells (domestic or privately owned public water supplies) while Community 2 was connected to the municipal public water system. The HIA determined levels of As, total dissolved solids (salts), and total coliforms by testing household water samples. The HIA results identified that thirty-two percent of the household water samples had As levels greater than the EPA maximum contaminant level (MCL) of 10 µg/L, with a mean (SD) value of 0.78 (±0.30) µg/dL and range of 0.26-1.58 µg/dL. The households with the highest As values had water supplies from wells (water from domestic wells or water from privately owned wells made available to the public) in Community 1 (1.9±0.9) µg/dL. It was noted that one household from Community 2 which was connected to the municipal public water system, exceeded the EPA's MCL.

For the current study, because Community 2 as compared to Community 1 was connected to the municipal public water system, School 2 was envisioned as a control group for household As levels. This study attempted to determine whether child blood As levels were predicted by household water As levels tested at the time of the child studies. We also wanted to know if Pb was present in household water because Pb can also contaminate tap water and have an ill-effect on children. We also examined whether either of these two metals predicted child behavior.

4.2 Summary of Major Findings

A total of 123 participants were initially recruited, 118 were tested, and complete data from a final sample of 104 were available for these analyses. Children were tested during physical education class times on regular school calendar days in April 2014. Family demographic data, child health history, and parent report of child behavior (SDQ) were collected at the time of recruitment during parent/teacher meeting nights. Household water samples were collected during three weeks in June 2014.

In the initial examination of the descriptive data, less than eight percent, that is, six out of seventy-three household water samples tested, had As levels exceeding the EPA's MCL and all of these were from Community 1. This confirmed our expectation that household in Community 1 were more likely to have As in home water samples due to naturally occurring As in the groundwater of the southwest. At the same time, we had many children from both schools (approximately 65% of children from both communities) with As mean blood levels exceeding the allowable limit of 1.2µg/dL and these belonged to households whose As levels were less than the EPA's MCL.

The primary analysis demonstrated that arsenic in household water predicted child blood As level. For every one unit increase of As in home water samples, child blood As level increased by 0.26 µg/dL. There was no association found between As and child behavior. There were no Pb levels of concern identified in household water samples, and most of them measured zero. Yet, Pb levels were detectable in children, raising concerns for sources of Pb for these children, since there is no safe threshold for Pb in children. Because household water sample levels were not detectable in most cases, analyses of the association between Pb household levels and child blood Pb were not conducted. There were no associations found between Pb and child behavior. Our study identified five key findings, explained below. Furthermore, the analysis of descriptive data demonstrated that the schools differed significantly in child As and Fe levels, and in household As and pH values, models that were controlled by sex and school.

4.3 Child As Blood Levels Exceeded Acceptable Limit

The child mean blood As values from both schools (communities) exceeded the allowable arsenic blood level limit. At the same time, As levels in the household water samples were less than the EPA's MCL for As, and there was a significant association between household water As levels and child blood As. In these analyses, sex and age did not explain differences in child blood As levels. There are likely to be factors other than the water supply that contributed to child As levels such as exposure to contaminated soil, air, or foods (U.S.EPA, 2006). Nonetheless, this combination of findings may suggest that the MCL for As in home water supplies is currently too high. As in the home water supply at levels well below the MCL may be producing higher than acceptable blood As levels in children.

Initially, School 2 (Community 2) was regarded as a control population for our study because children in this community lived in houses with access to the municipal water system, while children from School 1 (Community 1) lived in houses that had only groundwater sources which in the southwest are more likely to be contaminated by naturally occurring As. This was confirmed in the HIA findings (Hargrove et al., 2015) and, based on those findings; we expected that approximately one-third of households tested in Community 1 (the same community tested in the HIA) would have exceeded the As MCL. Our findings did confirm that Community 1 had significantly higher levels of As in household water than Community 2. Only 6/32 households in Community 1 however had water As above the MCL.

It is important to recognize that associations found between household water arsenic and child blood As have typically been reported in the literature when water arsenic levels exceeded the MCL (Rocha-Amador et al., 2007; Tsai, Chou, The, Chen, & Chen, 2003; von Ehrenstein et al., 2007; Wasserman et al., 2007; Wasserman et al., 2004). Our findings show that whether household water samples exceed the MCL limit for As is not a complete indicator of whether or not children are experiencing significant exposure to As. The fact that our study found an association between household levels and child blood levels, even when household water levels were below the current MCL, is very important because it suggests that children can accumulate As even from water with a measureable As level well below the current recommended MCL.

4.4 Similarities and Differences between the Communities

The communities were very similar with regard to geographical location, ethnicity, and family income. There were significant differences however between the two communities with regard to child blood As and Fe levels, and household As and pH levels.

In our study, the primary difference between these communities was that the households of children from Community 1 relied entirely on groundwater sources (private or public local wells) while households of children from Community 2 had water supplied by the municipal public water system. As expected, given the natural occurrence of As in ground water of the southwest, the findings showed that As was significantly higher in households from Community 1. Perhaps connecting municipal public water system in this region reduces the risk of As in the water, but not in the child.

4.5 Contribution of Sex Differences to Outcomes

Our study also determined that sex was not a contributing factor to As levels in children, contrary to some sex differences we have seen in children, where boys because of their higher red blood cell count have higher Pb levels than girls (Sobin et al., 2009, 2011; Liu, Huo, Zhang, Li, and Xu, 2015).

With regard to blood Fe levels, the significant effect of sex confirms what has already been noted in the literature. Males have higher red blood cell count (hematocrit) than females and therefore have higher Fe levels (Mayo Clinic, 2015).

4.6 pH Levels in Household Water Samples

As level and pH level in household water samples from Community 1 were significantly higher than in Community 2. In exploratory analyses we examined the single-order correlations between household tap water pH and As levels in Community 1 ($r = 0.18$) and Community 2 ($r = 0.16$) and neither of these were statistically significant. Previous tests of associations between pH and As levels in ground water sources from across the U.S., and particularly in the western U.S. have shown significant correlations (Anning, et al., 2012; Welch, Westjohn, Helsel, & Wanty, 2000). The range of pH values in this sample was relatively small (6.39 to 8.21) and additional studies are needed to determine water pH and As levels from each water source over time to better examine possible relationships.

The reason we see an association between As and pH level is that the solubility of the source minerals containing arsenic found in water sources, such as iron oxides and sulfide minerals, are caused to release arsenic as pH levels increases (as the water becomes more alkaline) (Welch et al., 2000).

Logically, one might suggest that controlling pH in water sources could reduce As, however since the source of As is in the minerals, and because pH levels are almost impossible to hold at one level, the best solution is to remove the source minerals from the water using appropriate filters (Walker, 2015, private communication). Perhaps this is the same logic that explains why Community 2 has lower pH and lower As levels than Community 1, because public municipal water systems filter some source minerals along with other contributing factors that could alter pH and eventually affect As levels.

4.7 Iron Levels Different between Communities

Children in Community 1 had higher blood iron than children in Community 2. There is no standard for iron levels measured in whole blood of children using ICP-MS, and therefore our levels have no relation to clinical significance. Iron levels for clinical significance are tested measuring other biomarkers such as hematocrit, serum ferritin, serum iron, and total iron capacity, and are tested with blood extracted intravenously. Serum iron normal levels for children are between 50-120µg/dL and are dependent on the time of day it is tested (U.S. NLM, 2015). Our findings may serve as reference values for children Fe measured using ICP-MS, and may identify the method as a less invasive procedure for children. As described before, ICP-MS is a sensitive and reliable method, and does not need large amounts to quantify certain element.

Perhaps the finding can indicate a difference in nutrition, since Fe levels measured clinically reflect anemia or nutrition deficiency, like iron deficiency anemia (Alton, 2005). The other question will be to find out why the community that is connected to public municipal water system had significantly lower Fe levels than the other community who is not connected.

4.8 Blood Arsenic Levels and Child Behavior

Arsenic and lead were not predictive of child behavior. It could be that our tool was not sensitive enough to capture the behavioral concerns that the educators were identifying in our first meetings with them. It may also be that another behavioral assessment may be used in conjunction with the SDQ to better assess hyperactivity and attention deficiency. It would also be better if the SDQ were completed by children's teachers to assess behavior in school setting.

This in itself is a challenge though because teachers have limited time to answer SDQ forms for hundreds of children.

There is also the possibility that the parents did not complete the SDQ with accuracy, and with fair judgment, since the SDQ's were completed along with participant consent form, family and child history form, during parent teacher night, and while we were providing small incentives. Parents might have felt overwhelmed by the circumstances and environment, or just wanted to complete everything as quickly as possible to get the incentive. Another factor could be that parents completed the SDQ, which ask about sensitive data, before any trust had been established. Perhaps the way the SDQ was administered did not provide a good opportunity for parents to reflect on children's behavior and give the assessment the consideration it required.

Our findings did not suggest a relationship between arsenic and behavior, even though associations between child blood As level and cognitive function have been reported in the literature (Introduction, page 5-10). It is still possible that arsenic may cause behavioral problems in children, and perhaps our study approach was not sensitive enough to find associations.

The possibility that arsenic may cause behavioral problems is based on an understanding of the mechanisms by which arsenic affects the brain. One way this can happen is that arsenic increases oxidative stress in the body affecting all types of cells, including neurons (Hinhumpatch et al., 2013; Wong et al., 2005). Oxidative stress increases the production of cell byproducts that are toxic to cells and damage DNA, a process that eventually alters normal cell functions, even killing the cell. In the case of neurons, oxidative stress affects neurite growth, shortening the communication components of a neuron, axons and dendrites (Sampayo-Reyes et al., 2010; X. Wang et al., 2010). Compromising the communication components of neurons also means miscommunication between brain regions. Miscommunication between brain regions are responsible for disrupting the integration and interpretation of information collected through our different senses, and can affect many complex human functions, such as cognition and behavior.

Another way that arsenic affects the brain is that it affects the N-methyl-D-aspartate receptor (NMDA) receptors in the hippocampus, the area responsible for learning and memory (Blanke, 2009; Huo et al., 2014; Kruger et al., 2009; Luo et al., 2009; Rodriguez-Barranco et al., 2013; Wong et al., 2005). This may partly explain why learning disabilities have been found in children with arsenic exposure. A disruption in NMDA receptors during a child's development can impact basic learning and memory functions. Arsenic affects NMDA receptors by reducing their expression in the hippocampus, and interfering with cell communication (Luo et al., 2012) or by causing NMDA receptors to block the balance of the neurotransmitter glutamate, overexciting and killing neurons (Huo et al., 2014). Both of these alterations to NMDA receptors may cause communication problems between neurons, and in the hippocampus, a region of the brain critical for learning and memory.

While our studies also did not show that there was an association between lead and behavior, there is significant evidence in the literature that suggests otherwise. Although it has not been clearly demonstrated, it is believed that the reason lead changes behavior is because it affects the brain. Lead has been determined to be a "neurotoxicant." It is believed that lead crosses the blood brain barrier because the shape of lead particles mimics the structure of calcium. Once in the brain, studies have suggested that lead interferes with neurotransmission, cellular migration and with synaptic plasticity in the central nervous system (Woolf et al., 2007). Lead can also cause neurons to program cell death (apoptosis), overexcite (excitoxicity), and interfere with neurotransmitter storage (Lidsky & Schneider, 2003).

Lead not only affects brain cells, but lead affects other types of cells found in the brain such as astroglia and oligodendroglia. These cells play a role in providing nutrients and protection to brain cells (Woolf et al., 2007). All of these effects could be responsible for the disruption of neurodevelopment.

During early and middle childhood, the brain and its functional regions develop and integrate (Hamadani et al., 2011). It is during this period that children begin to learn critical thinking and problem solving. Any interference from heavy metals like arsenic and lead exposure can interfere with the development of perception and behavior including hearing, seeing, memory, social behavior, and control of movements in the body cognitive, behavioral, and motor skills (Argos et al., 2010; Grandjean & Landrigan, 2006; Rodriguez-Barranco et al., 2013; Rosado et al., 2007).

It is also important to note that in these schools nurses, coaches, and school principals expressed significant concern regarding children's behavior, especially with regard to hyperactivity and attention deficits. More in-depth analysis of children's behaviors at these schools should be completed by having teachers rate classroom behavior over time.

4.9 Next Steps

There are several follow up studies that need to be conducted to confirm findings in this study: 1) children must be retested to see if arsenic and lead blood levels are consistent with study findings; 2) household water samples need to be retested as well to confirm arsenic exposure and association with child arsenic levels; 3) exposure sources for arsenic and lead in these two communities need to be identified.

Seasonal factors that may influence water and child arsenic levels will need to be considered during retesting phase. It may be possible that variability from stress related to annual standardized testing from schools, and to season change (winter vs. summer) can have an effect on child blood levels. Testing every 6 months may control for such seasonal factors and testing periods. If children continue to have such levels exceeding the allowable limit, we then can assume that there is a constant arsenic exposure.

While household As levels predicted child As levels, we still do not know how arsenic gets into the child. Identifying the intermediate steps of how household water As predicts child As will help us understand the relationship between household water samples and children. In order to understand the relationship, we need to identify water consumption patterns and sources, dietary/nutrition patterns, outdoor activity and other sources of possible environmental contamination by location of residence. Identifying the intermediate steps, the route of exposure between household water As and child As can then be the target point of intervention to prevent As exposure in children by this relationship.

While child arsenic levels were the main finding in our studies, we cannot ignore the fact that there were child lead levels identified in both communities, and that the source is not yet identified. Aside from investigating probable sources from dietary patterns, contamination in soil and air need to be ruled out. Environmental (soil and air) contamination from industrial sites is known to occur in this region. Therefore it makes sense to identify industrial sites near the communities and research their impact on the community's environment. At the moment there are two known industrial sites that are near the communities. Environmental studies that include soil and air sampling for heavy metals in different diameter distances from the industrial sites need to be conducted.

We would also want to address other community health concerns and to further build the trust with the communities. During the research, community members from both communities confronted us with perceptions that there was a high incidence of cancer and cancer related deaths in community members of all ages. They reported that the most common types of cancers were lung and kidney cancers. Community members perceived the environment to be the cause of such health conditions, and expressed frustration towards myths regarding how they lived in contaminated water, air, and soil. In order to address community concerns, and to debunk environmental contamination myths, family histories of many chronic and acute diseases, along with the environmental tests need to be conducted. The rural demographics of these two communities, and their high transient rates, have resulted in virtually no reliable disease registry or health monitoring for these two communities.

We truly value the relationship with these communities. Bilingual (English-Spanish) researchers, students, and administration helped build the trust in the community. The children recognized us as non-threatening figures, leading to parent and family trust. We also recognized that having the support of the local authorities, and the school district helped us work with the community. Through the schools, we had nurses working with us to explain results and address health concerns of parents regarding As levels in children. The school's parent liaisons coordinated resources during testing of children. From the relationship built in the schools, we had the privilege to gain the families' trust and they welcomed us into their homes to obtain household water sample.

We feel that that these communities are in great need of having the arsenic and lead exposure sources identified, and are well-aware that these levels can be detrimental to the health of the children living in these communities. In the meantime, we should develop immediate interventions that will limit the exposure to these heavy metals. Immediate interventions can include community education on identifying possible sources and limiting exposure to sources of these two heavy metals, including limiting consumption of food with heavy metals and maintaining the essential vitamins and minerals that protect from heavy metal absorption.

Conclusion

Regardless of household water source (groundwater from private wells in Community 1 or water from the public municipal system in Community 2) a majority of children had blood As levels above the acceptable limit. Household water As levels predicted a significant proportion of variance in child blood As levels. For every one unit increase of As in home water samples, child blood As level increased by 0.26 µg/dL. At the same time, the remaining unexplained variance in the model suggested that other sources of exposure are also contributing to child blood As levels. Also, secondary comparisons of health variables showed that, as compared to children in Community 2, children in Community 1 had significantly lower blood iron levels raising questions about nutrition in this community.

Arsenic blood levels in children from these two communities must be monitored, and the other possible sources of contamination, such as soil and air, must be tested. To the extent that child blood As levels in this study were attributable to water As, these findings suggested home tap water with As below the current MCL (1.0 µg/dL) may have contributed to child blood As levels above the acceptable limit (1.2 µg/dL). Concerns of parents and teachers regarding child As exposure must be addressed in ongoing interactions with the communities and education about nutrition must be provided to the communities.

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Appendix A

Health and Personal History

University of Texas El Paso, Department of Public Health Sciences

Child Health Screening Project

Referral Source: ____________________ **Date:** _______________

Mother's Name: ______________________ **Father's Name:** _______________________________

Child Name ________________________________ (Last / First)	**Study ID #** **61** - ___ ___ ___ - ___ ___ ___ (Study / Family / Proband)

Address ____ **Phone #1** _________________________

City ______________________ **State** _________ **Zip**___________ **Phone #2** _______________

SEX male female	**DOB** __ __ __ __ __ __ (month day year) **Current Age** _____________
Mother's Education (check one): _____ Completed grades 1-6 _____ Completed some high school _____ Graduated High School _____ Completed some college _____ Graduated college (BA, BS) _____ Complete some graduate school _____ Completed graduate degree (MA, MS) _____ More than graduate school education	**Father's Education (check one):** _____ Completed grades 1-6 _____ Completed some high school _____ Graduated High School _____ Completed some college _____ Graduated college (BA, BS) _____ Complete some graduate school _____ Completed graduate degree (MA, MS) _____ More than graduate school education

Child's RACE/ETHNICITY:	**Mother's RACE/ETHNICITY:**	**Father's RACE/ETHNICITY:**
Please circle all that apply:	***Please circle all that apply:***	***Please circle all that apply:***
Alaska Native	Alaska Native	Alaska Native
African American	African American	African American
American Indian	American Indian	American Indian
Asian	Asian	Asian
Black	Black	Black
Hispanic	Hispanic	Hispanic
Latino	Latino	Latino
Mexican	Mexican	Mexican
Mexican American	Mexican American	Mexican American
Native Hawaiian	Native Hawaiian	Native Hawaiian
Pacific Islander	Pacific Islander	Pacific Islander
White	White	White

WHICH HAND DOES YOUR CHILD USE FOR WRITING?	**HANDEDNESS:** left right ambidextrous (both equally)
WHAT TYPE OF SCHOOL DOES YOUR CHILD ATTEND?	**SCHOOL:** 1 public 2 private 3 special education 4 private tutor/home school 5 preschool/daycare 6 other/none _____________________
WHAT GRADE IS YOUR CHILD IN?	**Current Grade:** preK K 1st 2nd 3rd 4th 5th 6th

Does anyone smoke at home?   YES   NO

If yes, who and for how long:

____

____

____

How many family members live at home (circle one):   2   3   4   5   6   7   8   9   10 or more

The yearly income of your family is (circle one): ____________________________

WHERE HAS YOUR CHILD LIVED?	CITY, STATE	ZIP CODE
AGE 1		
AGE 2		
AGE 3		
AGE 4		
AGE 5		
AGE 6		
AGE 7		
AGE 8		
AGE 9		
AGE 10		
AGE 11		
AGE 12		

Has you child ever been tested for arsenic, cadmium, mercury or lead? **YES** **NO**

If yes, what was your child tested for? (circle all that apply) **arsenic** **cadmium** **mercury** **lead**

When: ________________________ **What was the result?** ____

When: ________________________ **What was the result?** ____

When: ________________________ **What was the result?** ____

Has anyone in your family been told that they have high levels of (circle all that apply):

arsenic **cadmium** **mercury** **lead?** **YES** **NO**

If yes,

When: ________________________ **What was the result?** ____

When: ________________________ **What was the result?** ____

When: ________________________ **What was the result?** ____

Was the source of the lead identified? **YES** **NO**

What was it? ____

____

Have you ever been told your child has any of the following:

Learning disability	**Attention Problems**
Slow or delayed development	**Stuttering**
Mental retardation	**Eye problems**
Pica (eating dirt or other non-food items)	**Hearing Loss**
Behavior Disorder	

Do you have any concerns about your child's behavior or development? If yes, please explain:

____

____

____

____

____

____

____

History of other serious diagnoses, medical disorder(s) or hospitalization(s):

____

____

____

____

____

____

____

____

Is there anything else you would like to tell us about your child's health and development?

____

____

____

____

____

____

____

____

____

____

____

____

Thank you for your time!

Appendix B

Strengths and Difficulties Questionnaire

P 4-10

For each item, please mark the box for Not True, Somewhat True or Certainly True. It would help us if you answered all items as best you can even if you are not absolutely certain. Please give your answers on the basis of your child's behavior over the last six months.

Your child's name .... Male/Female

Date of birth..

	Not True	Somewhat True	Certainly True
Considerate of other people's feelings	☐	☐	☐
Restless, overactive, cannot stay still for long	☐	☐	☐
Often complains of headaches, stomach-aches or sickness	☐	☐	☐
Shares readily with other children, for example toys, treats, pencils	☐	☐	☐
Often loses temper	☐	☐	☐
Rather solitary, prefers to play alone	☐	☐	☐
Generally well behaved, usually does what adults request	☐	☐	☐
Many worries or often seems worried	☐	☐	☐
Helpful if someone is hurt, upset or feeling ill	☐	☐	☐
Constantly fidgeting or squirming	☐	☐	☐
Has at least one good friend	☐	☐	☐
Often fights with other children or bullies them	☐	☐	☐
Often unhappy, depressed or tearful	☐	☐	☐
Generally liked by other children	☐	☐	☐
Easily distracted, concentration wanders	☐	☐	☐
Nervous or clingy in new situations, easily loses confidence	☐	☐	☐
Kind to younger children	☐	☐	☐
Often lies or cheats	☐	☐	☐
Picked on or bullied by other children	☐	☐	☐
Often offers to help others (parents, teachers, other children)	☐	☐	☐
Thinks things out before acting	☐	☐	☐
Steals from home, school or elsewhere	☐	☐	☐
Gets along better with adults than with other children	☐	☐	☐
Many fears, easily scared	☐	☐	☐
Good attention span, sees chores or homework through to the end	☐	☐	☐

Do you have any other comments or concerns?

Please turn over - there are a few more questions on the other side

Overall, do you think that your child has difficulties in one or more of the following areas: emotions, concentration, behavior or being able to get on with other people?

No	Yes- minor difficulties	Yes- definite difficulties	Yes- severe difficulties
☐	☐	☐	☐

If you have answered "Yes", please answer the following questions about these difficulties:

- How long have these difficulties been present?

Less than a month	1-5 months	6-12 months	Over a year
☐	☐	☐	☐

- Do the difficulties upset or distress your child?

Not at all	Only a little	Quite a lot	A great deal
☐	☐	☐	☐

- Do the difficulties interfere with your child's everyday life in the following areas?

	Not at all	Only a little	Quite a lot	A great deal
HOME LIFE	☐	☐	☐	☐
FRIENDSHIPS	☐	☐	☐	☐
CLASSROOM LEARNING	☐	☐	☐	☐
LEISURE ACTIVITIES	☐	☐	☐	☐

- Do the difficulties put a burden on you or the family as a whole?

Not at all	Only a little	Quite a lot	A great deal
☐	☐	☐	☐

Signature .... Date ....

Mother/Father/Other (please specify:)

Thank you very much for your help

Appendix C

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Child(ren) Name(s):		
	Last	First
	Last	First
	Last	First
	Last	First
Child(ren) Study ID(s):	XX-XXX-XX	
	XX -	-
	XX - ___________	- ____________
	XX -	-
Address:		
Name and Relationship to Child:		
Gender (Circle One):	Male	Female
Date of Birth and Age (in years):		

Water Source Questions:

1. Where does your household water come from? Private (Wells) Public Municipal Water System Other
2. If water is from private source (Wells), how often is your water tested? Every day Every Month Twice a year Every Year Do not Know
3. Where do you primarily get your drinking water? From Tap Store bought (bottle water) Other
4. If drinking water comes from tap, do you filter? Yes No
5. If drinking water is store bought, how many times you purchase water in a month? (Based on previous 6 months) Once Twice Three Four or More
6. How much does it cost to purchase your drinking water, per month?

Water Consumption Questions:

7. How many times of your primary drinking water source do you drink in a week? Once Twice Three Four or More
8a. How many times of your primary drinking water source does your child drink in a week? (continue for multiple children at home) Once Twice Three Four or More

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8b. How many times of your primary drinking water source does your child drink in a week? Once Twice Three Four or More
8c. How many times of your primary drinking water source does your child drink in a week? Once Twice Three Four or More
8d. How many times of your primary drinking water source does your child drink in a week? Once Twice Three Four or More
9a. How many times of your primary drinking water source does your child drink in a day? (Continue for multiple children at home) Once Twice Three Four or More
9b. How many times of your primary drinking water source does your child drink in a day? Once Twice Three Four or More
9c. How many times of your primary drinking water source does your child drink in a day? Once Twice Three Four or More
9d. How many times of your primary drinking water source does your child drink in a day? Once Twice Three Four or More

Water Quality Questions:

10. Rate the water quality in your area: Poor Fair Good
11. How would your neighbors rate the quality of the water in your area? Poor Fair Good
12. Do you feel your water is safe to drink in your area? Yes No Not Sure
13. How safe do you think your water is to drink? Not at all Safe Very Safe Unsure
14. How satisfied are you with the taste of your tap water? Poorly Fairly Very
15. How satisfied are you with the color of your tap water? Poorly Fairly Very
16. How satisfied are you with the odor of your tap water? Poor Fairly Very
17. Do you think your tap water meets federal safety standards? Yes No Not Sure

Water and Health Questions:

18. Have you or any member of your household have had gastrointestinal (cramps, diarrhea, abdominal pain) problems in the past 6 months? No Yes If yes, who_____________________ and when_____________________
19. Do you know of any health problems that might come from consuming bad quality water?

Interviewed by:_____________________
Date:_______ Time: _______

Curriculum Vita

Michelle Del Rio was born and raised in El Paso, Texas. She is the oldest of three siblings, and was the first of her family to go to college. At the University of Texas at El Paso (UTEP), she was a member of the Medical Professions Organization, and was one of eleven UTEP students who successfully revived the Mariachi Los Mineros. She graduated in 2010 with a Bachelor's of Science degree in Biomedical Sciences and was the first in the College of Sciences to graduate with three minors: Chemistry, Psychology, and Spanish. After graduation, she worked at Texas Tech University Paul L. Foster School of Medicine and Biomedical Sciences in the Histology Research core facility as the lead technician of the core. Also during this time, Michelle was president of the Association of Women in Sciences for the El Paso chapter, where she helped to create a mentorship program for local high school girls, and had the honor of attending the White House event in Washington, D.C., that introduced the National Science Foundation (NSF) work-family-friendly policy for Science Technology Engineering, and Mathematics (STEM) sectors, and also had the honor of introducing Ms. Michelle Obama. After a year of working at Texas Tech, Michelle was accepted into the Masters of Public Health degree program at UTEP. She completed her course work while working at Texas Tech, which included a practicum at the Pan American Health Organization (PAHO) where she contributed to the completion of a major epidemiological database of mortality rates for communities along the U.S. and Mexican border regions, and afterwards was hired as a special consultant to collect qualitative data for studies of Promotoras effectiveness in the border region. In fall 2014, Michelle accepted a position as Program Manager/Coordinator for the Center of Environmental Resource Management where she manages Health Impact Assessments examining resource issues along the U.S. Mexico border.

Michelle plans to attend to medical school. Afterwards she will combine her public health sciences and research backgrounds with her medical training to continue to address and resolve public health issues along the U.S. Mexico border. She hopes to one day create a special community center dedicated to health services and community health research.

Permanent address: 4608 Round Rock, Dr. El Paso, Texas, 79924

This thesis/dissertation was typed by Michelle Del Rio.