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Pediatric anxiety and/or depression problems : associations with PM10, fly ash, and metal exposure.

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PEDIATRIC ANXIETY AND/OR DEPRESSION PROBLEMS: ASSOCIATIONS WITH PM_{10}, FLY ASH, AND METAL EXPOSURE

By

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M.P.H., Wright State University, 2012

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ABSTRACT

PEDIATRIC ANXIETY AND/OR DEPRESSION PROBLEMS: ASSOCIATIONS WITH PM_{10}, FLY ASH, AND METAL EXPOSURE

Abby Nicole Burns Hagemeyer

April 20, 2017

Background: In the last several decades, the use of coal has become more prevalent in turn increasing the amount of coal ash being produced. Coal ash, the by-product of coal combustion, is composed of small particles that contain essential elements, hazardous metals, polycyclic aromatic hydrocarbons, and radioactive material. While a small proportion of coal ash is reused, the majority gets discarded in open-air landfills and ash ponds. Fly ash, the major component of coal ash, can become emitted into the air and potentially contribute to the air pollution and metal exposure in the surrounding community. Few studies, particularly in the United States, have investigated the relationship between coal ash and adverse health effects in children. Furthermore, because children are still developing both physically and neurologically they are more susceptible to the potential harms of coal ash and more vulnerable to the excess exposure of heavy metals and essential elements found in coal ash. The United States Environmental Protection Agency estimates that 1.5 million children are exposed to coal ash. Though the mechanisms are still unclear, metal exposure has been linked to mood disorders, such as anxiety and depression. The goal of this study was to examine the relationship between PM_{10}, fly ash, and metal exposure and anxiety and/or depression problems in children aged 6-14 years, living near two coal ash storage facilities, and who were recruited in the first 16 months of an ongoing study.

Methods: To determine anxiety and depression, the Child Behavior Checklist (CBCL) was completed for children residing in neighborhoods surrounding two large coal ash storage facilities. In-home air samples were collected and analyzed with Proton-Induced X-ray Emission (PIXE) and Scanning Electron Microscopy (SEM) to assess PM_{10}, fly ash, and home environmental metal exposure. Toenail and fingernail samples were collected and analyzed with PIXE to assess metal body burden exposure. Logistic regression models, adjusting for potential covariates, were used to assess the relationship between in-home PM_{10}, fly ash, metal exposure, and metal body burden and three primary outcomes determined from the CBCL: anxiety problems, withdrawn/depressed problems, and anxious/depressed problems.

Results: High copper body burden was significantly associated with anxiety problems (AOR=10.3, 95% CI: 1.53-69.3, p-value=0.02), withdrawn/depressed problems (AOR=21.7, 95% CI: 1.96-240, p-value=0.01), and anxious/depressed problems (AOR=52.1, 95% CI: 2.96-919, p-value=0.01). Presence of manganese in the body was significantly associated with anxiety problems (AOR=9.03, 95% CI: 1.40-58.4, p-value=0.02) and anxious/depressed problems (AOR=8.72, 95% CI: 1.39-54.7, p-value=0.02). High filter metal score was significantly associated with withdrawn/depressed problems (AOR=0.14, 95% CI: 0.03-0.80, p-value=0.03).

Conclusions: The results of this study use preliminary data from the overarching and ongoing study and should therefore by interpreted with caution. Findings are based on the recruited population from September 2015 through January 2017. These findings

suggest that more studies are needed to comprehensively examine the relationship between PM_{10}, fly ash, and metal exposure, in the home environment and metal body burden, and pediatric anxiety and/or depression problems, particularly in regards to exposure that may be from coal ash.

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INTRODUCTION

Specific Aims

Fugitive fly ash from coal ash storage and power plant stacks can increase the amount of ambient air pollution in neighborhoods surrounding coal burning power plants. Consequently, children in these neighborhoods may have increased exposure to ambient air pollution and various heavy metals. Excess air particulate matter and metal exposure can cause a wide range of physical and mental disruptions in the body. Psychological imbalances can range across both internalizing and externalizing behaviors such as depression, anxiety, and violent or aggressive behaviors. ***The central hypothesis of this dissertation is that: children with increased exposure to particulate matter, fly ash, and metals in their home environment and metals in their bodies have higher odds of anxiety and/or depression problems.***

This hypothesis will be explored through the following three specific aims:

Specific Aim 1: *Evaluate the roles of PM_{10} and fly ash in the home environment on anxiety and/or depression problems in children, as indicated by the Child Behavior Checklist.* Working Hypothesis: Children with elevated PM_{10} concentrations in their home environment (as determined from air filter analysis) are more likely to be anxious and/or depressed than children with lower concentrations of PM_{10}. Children with fly ash in their home environment are more likely to be anxious and/or depressed than children without fly ash in their homes.

Subaim 1A. Determine if children with elevated PM_{10} concentrations or fly ash in their home environment have higher odds of anxiety problems than children with low PM_{10} concentrations and no fly ash.

Subaim 1B. Determine if children with elevated PM_{10} concentrations or fly ash in their home environment have higher odds of depression problems than children with low PM_{10} concentrations and no fly ash.

Subaim 1C. Determine if children with elevated PM_{10} concentrations or fly ash in their home environment have higher odds of anxiety and/or depression problems than children with low PM_{10} concentrations and no fly ash.

Specific Aim 2: *Determine the effects of elevated metal concentrations in the home environment on anxiety and/or depression problems in children.* Working Hypothesis: Children with elevated metal concentrations found in their home environment (as determined from air filter analysis) are more likely to be anxious and/or depressed than children with lower metal concentrations.

Subaim 2A. Determine if children with elevated metal concentrations in their home environment have higher odds of anxiety problems than children with lower metal concentrations.

Subaim 2B. Determine if children with elevated metal concentrations in their home environment have higher odds of depression problems than children with lower metal concentrations.

Subaim 2C. Determine if children with elevated metal concentrations in their home environment have higher odds of anxiety and/or depression problems than children with lower metal concentrations.

Specific Aim 3: *Determine the effects of elevated metal concentrations in the body on anxiety and/or depression problems in children.* Working Hypothesis: Children with elevated metal concentrations found in their bodies are more likely to be anxious and/or depressed than children with lower metal concentrations.

Subaim 3A. Determine if children with elevated metal body burdens have higher odds of anxiety problems than children with lower metal body burdens.

Subaim 3B. Determine if children with elevated metal body burdens have higher odds of depression problems than children with lower metal body burdens.

Subaim 3C. Determine if children with elevated metal body burdens have higher odds of anxiety and/or depression problems than children with lower metal body burdens.

Background

Coal Ash and Its Components

Coal, a combustible organic sedimentary rock, is largely formed from plant debris and is comprised of sulfur, carbon, oxygen, hydrogen, and nitrogen as well as small amounts of various heavy metals and radioactive material (1, 2). Coal is primarily mined for the world's increasing demand of fuel; coal combustion power plants continue to act as a major contributor to electricity production despite efforts to increase natural gas production (1, 3). In 2014, the United States consumed 917.7 million short tons of coal; one short ton is equivalent to 2000 pounds (4). Of this, 92.8% was used for electric power production in the 491 operational coal-fired power plants across the United States.

Steam or thermal power plants are widely used to generate electricity in the United States. Many of these facilities utilize a process known as pulverized coal combustion (PCC) to transform mechanical energy into electrical energy (5). In this process, coal is pulverized into a fine powder, increasing the surface area to allow the coal to burn more quickly. In a combustion chamber that is lined with water-filled tubes, coal is burned at a high temperature to produce gases and heat energy (6). This heat converts the water into high-pressure steam that is then funneled into compartments containing a steam turbine and generator. When the steam enters, it rotates propeller-like blades connected to a rotor shaft. The rotor is attached to coil containing magnets inside a generator. When the coils rapidly rotate, a magnetic field is produced and the generator converts mechanical energy into electrical energy.

Electrical energy is the desired outcome, but the process does not stop there. Coal combustion generates a byproduct, commonly known as coal ash, which consists of small particles that contain polycyclic aromatic hydrocarbons; naturally occurring radioactive materials; and a variety of heavy metals including aluminum, arsenic, iron, lead, mercury, and copper (7-13). In 2014, the United States alone produced 130 million short tons of coal ash – a marked increase from the previous two years (14).

Coal ash, also known as coal combustion residuals (CCR), is an overarching term that includes flue gas desulfurization solids, boiler slag, bottom ash, and fly ash. Fly ash is the largest component of coal ash and is characterized by fine incombustible, inorganic material (3, 15). During the combustion process, residuals are carried in the flue gas pathway where some of the material will cool and condense into small, glassy spherules (15, 16). Most of these small, spherical fly ash particles measure ≤ 10 μm in diameter and account for 40-70% of coal ash products. In 2014, of the 130 million short tons of coal ash produced, 50 million short tons was attributed to fly ash waste (14).

In the past few decades, the U.S. Environmental Protection Agency (EPA) has lobbied for components of CCR to be reused. Because fly ash has similar characteristics to natural materials found in the earth's crust, it has been utilized in several applications. For example, fly ash is used in several industrial products such as concrete, aluminum metal alloys, and synthetic lumbers (17). However, nearly 52% of coal ash, and more specifically 54% of fly ash, go unused (17, 18). Instead, this waste gets transported to and stored in designated ash ponds and landfills where it becomes a likely source of pollution (19).

In 2014, 67.6 million short tons or 135.2 billion pounds of the coal ash produced was disposed of in more than 675 coal ash impoundments around the United States (20). Ash storage impoundments refer to coal ash ponds or landfills. Ash is combined with water and the slurry mixture is placed in ash ponds to be stored indefinitely. Eventually, the ash settles at the bottom of the pond, leaving a top layer of water that can be recycled to create the slurry ash mixture and returned to the pond (21). When the pond fills, the coal ash may need to be filtered out and transported to a landfill. Typically, the landfills are divided into sections so the coal ash can be stored in layers. Dry coal ash is transported from interim ash storage sites, ash ponds, or directly from the coal-fired plant by a haul truck (21, 22). Once the haul trucks dump the ash, it is then spread and leveled with a grading machine. Inevitably, dumping and grading dry ash produces dust, known as fugitive fly ash.

Regulations

The Resource Conservation and Recovery Act (RCRA) of 1978 was enacted by Congress as a response to the growing amount of waste, both municipal and industrial, in the United States (23). In this comprehensive environmental statute, the EPA was charged with identifying and stringently regulating hazardous wastes. In 1980, Congress passed the Solid Waste Disposal Act Amendments, including one known as the Bevill Amendment, which excluded combustion waste from fossil fuels: flue gas desulfurization solids, slag, bottom ash, and fly ash (24). Consequently, coal ash was initially excluded as a hazardous waste under RCRA Subtitle C, along with several other large-volume wastes, pending further research and regulatory recommendation by the EPA (25). In May 2000, the EPA concluded that coal combustion waste (CCW) did not fall under the regulation constraints of Subtitle C. Alternatively, the EPA classified coal ash disposal in landfills and ash ponds as a non-hazardous waste under Subtitle D. Consequently, under RCRA Subtitle D, coal ash disposal is not regulated by the federal government; instead, the responsibly falls on each state. Unfortunately, many state regulation standards and requirements are minimal, if they exist at all (2).

On December 22, 2008, structural failure of a coal ash pond at the Kingston Fossil Plant in the Tennessee Valley Authority (TVA) caused more than one billion gallons of coal ash to escape into the Emory River and spread over more than 300 acres of land surrounding the storage site (26). This catastrophic event destroyed three homes and severely damaged twenty-three more. In 2009, the TVA Office of Inspector General reported that management failed to provide proper maintenance and training (26). Furthermore, potential hazards relating to the integrity of the ash pond were largely ignored. In all, the TVA has spent approximately $1.2 billion in cleanup efforts. Unfortunately, no amount of money can restore the lasting environmental and health effects caused by inadequate engineering and maintenance of the ash pond facility due to lacking regulations.

As a response to this incident and the increasing concern about the health impacts of coal ash exposure, the EPA reevaluated its decision to classify CCWs as RCRA Subtitle D (2, 23). In June of 2010, two regulatory options under the RCRA were proposed. In the first option, the EPA would reverse the Bevill Amendment to classify coal ash as “special waste” and thereby subjecting CCWs to the more stringent Subtitle C requirements regarding transport, handling, disposal, and storage overseen by the federal government (2). In the second option proposed, which was very similar to the previous regulations of CCWs, coal ash would remain under Subtitle D as a “non-hazardous waste” and the EPA would develop standardized regulations for CCW disposal facilities. However, under Subtitle D the EPA does not have authorization to enforce these new standards regarding the Bevill wastes, rather the responsibility falls on the individual states and localities (23). Furthermore, the proposed regulations did not include standards for location of the storage facilities, ground water monitoring, liner requirements, and emissions from the unit or storage site (2).

Just months before the EPA released its final rule on coal ash disposal, another major coal ash spill occurred in Eden, North Carolina highlighting the importance for tougher coal ash disposal regulations. The coal ash impoundment at Duke Energy’s Dan River Plant was situated on top of two storm water drainpipes measuring 36 inches and 42 inches in diameter (27). On February 2, 2014, these drainpipes collapsed spilling nearly 27 million gallons of untreated wastewater and 39,000 tons of coal ash into the Dan River. Immediate affects were seen by the Dan River as the natural river flow was disturbed by the rapid release. Coal ash covered the riverbanks and in some areas settled several feet thick on the river bottom. Metals and trace elements, such as arsenic, copper, and selenium, released by the spill disrupted the chemistry of the river water, wreaking havoc on the aquatic population in this area (27). Ultimately, the natural ecosystem balance was severely disturbed. Effects of the spill spanned miles; just days later, ash deposits were detected 70 miles downstream at the Kerr Reservoir in Virginia. The EPA and U.S. Fish and Wildlife Service reported that coal ash deposited on the river floor ranged from several feet deep closest to the spill site to one-half inch deep nearly 68 miles downstream (27-29). Early estimates predicted cleanup costs to approach $300 million. However, the coal ash that spilled into the Dan River will have long, permeating effects to both the environment and health of the surrounding population; a cost that is immeasurable. In regards to the structure failure at the Kingston Plant and pipe collapse at the Dan River Plant, it is arguable that with more stringent regulations overseen by the federal government, these two horrific and catastrophic events could have been lessened or prevented all together.

Despite these two devastating and highly publicized coal ash spills, on December 19, 2014 the EPA released its final rule on coal ash; coal ash will remain under Subtitle D regulations as a non-hazardous waste. One important distinction is that exemption from Subtitle C regulation does not mean that the waste has been classified as a non-hazardous waste, rather that coal ash did not meet the regulatory definition of a hazardous waste defined by the EPA (23).

While regulations are still limited, under the final rule the EPA set up national minimum criteria for which coal ash surface impoundments and landfills must comply.

Both surface impoundments and landfills must meet requirements for groundwater monitoring and corrective action, closure and post closure care requirements, and recordkeeping, notification, and publically accessible internet site standards (30). Additionally, new and existing surface impoundments must meet requirements for location restrictions, structural integrity, hydraulic and hydrologic capacity, and fugitive dust controls. New surface impoundments must integrate either a composite liner or compacted soil liner into the construction design (30). New landfills will be subject to more stringent location requirements as well as be required to integrate a composite liner and a collection and removal system into the construction plan (30).

Coal Ash in Kentucky

In 2015, Kentucky ranked 3rd among coal producing states in the nation, mining 61 million short tons of coal (31). There are 21 energy-generating sites in Kentucky, which are home to more than 55 coal-fired generating units. Throughout the state of Kentucky, these coal-fired power plants consumed between 38.1-40.1 million short tons of coal in 2014 (31, 32). The CCR were then stored in one of the 43 ash impoundments dedicated for coal ash storage (33). Southwest Louisville was home to two coal-fired generating stations owned and operated by Louisville Gas and Electric (LG&E). One converted to natural gas in 2015. In 2014, together these plants utilized more than 5.1 million tons of coal, which accounted for 13% of Kentucky's coal consumption (31).

Cane Run Station

Cane Run Station, which is located in southwest Louisville, opened in 1954 as a coal-fired power generating station (31). In all, the Cane Run Station was home to six coal units – three of which were retired by 1987. With three coal boilers still in use and a capacity of 563 megawatts (MW), the Cane Run Station consumed 1.1 million short tons of coal in 2014. This accounted for nearly 2.5% of all coal consumed in Kentucky that year (32). In the summer of 2015, the last three coal units were shut down effectively ending the 61 year span of coal-fired power production and making way for the new facility that houses Kentucky's first plant to utilize natural gas combined cycle units (34). Though closing the coal-fired plant means ceasing future coal ash production at the Cane Run Station, it does not address the issue and continued pollution from the existing coal ash landfill and ash pond at this location.

Cane Run Station is home to a 52-acre coal ash pond and 110-acre landfill (35). In a 2010 inspection of the ash pond, engineers determined dam failure could potentially cause loss of life and is therefore considered to have a high hazard rating (36). In the spring of 2015, the plant started removing water from the pond. When the process is complete, the ash pond will be 17 feet high and be similar to the current landfill on site; a dome like landfill that stands 130 feet tall or roughly the height of a 13-story building. Though the plant has plans to cap the coal ash storage facility, it will likely become a latent environmental hazard. The hazard can lay dormant, but may surface if the coal ash storage site becomes disturbed by a natural disaster such as flooding of the Ohio River or tornado in the area (37).

Mill Creek Station

The Mill Creek Generating Station, situated just 11 miles south of the Cane Run Plant in southwest Louisville, began operations in 1972 (31). By 1982, Mill Creek had four coal units in use that create a capacity of 1,472 MW, making it the third largest generating station in Kentucky. In 2014, Mill Creek was responsible for consuming almost 4 million short tons of coal; this made up 10% of the total coal consumption in Kentucky (31).

This 544-acre facility houses one landfill, one main ash pond, and four smaller ponds (38). Originally, the landfill spanned 142 acres of the 544-acre facility (39). However, after expansion the landfill now sits on 206 acres east of the Ohio River. The main ash pond, which spans 79-acres, sits just east of the Ohio River and north of the Mill Creek power plant. Three of the pond's four sides (north, east, and west) are contained by embankments that range from 19 feet to 35 feet above the natural ground (40). The main ash pond has a total storage capacity of roughly 6.9 million cubic meters and as of late 2015 stored 6.2 million cubic yards of coal ash (38). In accordance with the EPA ruling to assess the safety and structural reliability of CCW impoundments across the United States, impoundments at Mill Creek were inspected in 2009. The main ash pond is located 500 feet west of residential homes and less than 1,000 feet from an elementary school. If the east wall of the impoundment collapsed, it could result in the loss of human life. For these reasons, the main ash pond was rated as having a high hazard potential (38).

Literature Review

Coal Ash and Health

The World Health Organization (WHO) defines human health as the "state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" (41). The lifecycle of coal involves mining, transporting, washing, pulverizing, combusting, and storing combustion waste; each of these stages affects human health (42). The earliest studies available on coal ash and human health focus on occupational health hazards, however more recent studies suggest that coal ash can impact the physical, mental, and especially the social well-being of the communities surrounding coal-fired power plants and coal ash storage facilities (42-47). Coal combustion and its waste products are known contributors to several diseases including heart disease, lung cancer, asthma, and stroke (42).

For several decades, coal ash has been studied in relation to occupational health hazards. In the 1980s, Bencko et al. (1980) published research that analyzed tumor mortality patterns among workers at a coal combustion plant (48). Specifically, researchers were examining the effect of high arsenic levels at one "exposed" plant compared to two plants with lower arsenic levels. They found that malignancy-caused death occurred at shorter exposure intervals and younger age groups for workers at the "exposed" plant when compared to the two control plants. Another study by Bencko et al. (1988) looked at this same population to examine immunological profiles (49). They found that workers in the "exposed" arsenic plant had significantly higher levels of ceruloplasmin, transferrin, and orosomucoid when compared to workers at the plants with lower arsenic exposure. These findings are consistent with other studies suggesting that exposed power plant workers experience higher cancer mortality rates when compared to power plant workers exposed to coal with normal arsenic levels. A case-control study conducted in Turkey by Celik et al. (2007) investigated cytogenetic damage of employees working in a coal-fired power plant compared to healthy controls (50). Investigators found that the mean frequencies of chromosomal aberrations, sister-chromatid exchanges, micronuclei, and polyploidy were all significantly elevated when compared to the controls. These findings may suggest that cumulatively, the various chemical compounds found in coal ash could cause important cytogenetic changes, which could lead to increased morbidity. Furthermore, the findings highlight the dire need for measures that reduce workers' exposure to all coal combustion wastes.

Several studies have focused on comparing occupational hazards of fly ash treatment plants and bottom ash recovery plants. A study published in 2008 by Liu et al. examined oxidative damage in workers at three fly ash treatment plants compared to workers at a bottom ash recovery plant in Taiwan (51). Researchers reported that workers at the fly ash plants had significantly higher plasma malondialdehyde when compared to workers at the bottom ash recovery plant. Authors hypothesized that the hazardous substances may have more potential to leach from the fly ash as opposed to the bottom ash. Looking at the same population of workers in Taiwan, Chen et al. (2010) examined DNA damage associated with occupational exposure (52). They concluded that workers at the three fly ash treatment plants had more DNA damage when compared to workers at the bottom ash recovery plant. Over the past few decades, several studies have explored the various health effects in workers of coal-burning power plants in many developed and developing countries. Unfortunately, occupational studies in the United States are still lacking.

In addition to occupational studies, research from China has been published that assesses coal ash and children's health. Children are especially vulnerable to environmentally sensitive elements, like those found in coal ash (43). One study by Tang et al. (2008) sought to determine how early exposure could impact children's health (53). The study concluded that the level of polycyclic aromatic hydrocarbon-DNA adducts in cord blood of newborns was associated with reductions in 2-year developmental quotients in both motor and language areas. Furthermore, the study found that in utero exposure to lead from the coal-fired power plant negatively affected social development. A study by Liang et al. (2010) determined that coal combusted fly ash is a dominant source of lead exposure for children living in Shanghai (54). A study by Tang et al. (2013) sought to evaluate the potential ecological and children's health risk in the area surrounding a coal-fired power plant (43). Investigators reported that soil samples downwind of the plant had elevated concentrations of environmentally sensitive elements, such as arsenic, cadmium, copper, chromium, nickel, zinc, manganese, and lead when compared to soil samples up wind of the plant. The hazard quotient of the soil samples downwind of the plant was calculated to be 1.5, suggesting a potential health hazard for children.

Air Pollution and Health

Fugitive fly ash emissions from coal ash storage facilities can be significant contributors to the concentration of particulate air pollution (42, 55). The term particulate air pollution encompasses any liquid droplet or solid particle suspended in the air (56). Some particles, like dust or pollen, come directly from a source such as a road or field (57). However, the majority of particles result from reacting with chemicals to form sulfides and nitrates. These particles are a product of industrialization and come from sources such as a power plant or car exhaust (56, 57). Particulate matter (PM) is characterized by the aerodynamic diameter, usually reported in micrometers (μm). In the early 1980's, studies determined that inhalable particles are those less than 10 μm, also known as PM_{10}. Similarly, $PM_{2.5}$ is defined as particulate matter that is less than 2.5 μm in aerodynamic diameter. In the last several decades, a growing body of epidemiological research strongly suggests an association between ambient air PM and adverse health outcomes (55, 58-61). Furthermore, more recent research points to a dose-response relationship as the PM decreases in size; correlation strength increases as the aerodynamic diameter moves from PM_{10} to $PM_{2.5}$ (58, 62, 63). While PM_{10} and $PM_{2.5}$ both have the potential to cause damage to tissue, $PM_{2.5}$ is capable of traveling deeper into the lungs by penetrating the alveolar gas-exchange region. Here, the particulate matter can enter the blood stream and travel throughout the body.

Coal ash, and fly ash in particular, has the potential to increase the amount of air pollution, which can in adversely affect the respiratory system, cardiovascular system, and central nervous system (42). While only a limited body of literature has examined the health effects associated with exposure to coal combustion residuals, a few studies have shown that coal combustion pollutants are associated with various respiratory problems (18, 42). Foreign particle exposure, like those introduced into the air by coal combustion, can cause particle-induced carcinogenesis (18). As seen in the occupational studies previously discussed, oxidative stress can be affected by coal ash exposure (42, 51, 52). Oxygen free radicals which are highly reactive molecules, can increase when exposed to high concentrations of air pollution and cause damage to DNA, lipids, cellular integrity, and proteins (42). Oxidative stress has been linked to hypertension, diabetes, atherosclerosis, and various neurological disorders, and will be discussed further in a subsequent section. Other adverse health effects of coal ash exposure include risk for impaired cardiovascular health and increased risk for stroke.

Children are among the most susceptible populations for adverse health outcomes associated with ambient air pollution (64). Because children have a higher respiratory rate and their lungs are still developing, and because children's lungs are smaller than fully developed adult lungs, the concentration of ambient air pollution they are exposed to is greater (64). The highly concentrated PM, which may contain heavy metals, can easily enter the blood stream and affect many physiological processes of the developing child (64). In addition to heavily concentrated ambient air pollution exposure, children are also more likely to have other risk factors such as hand to mouth behavior, which may further increase the body burden of certain heavy metals found in household dust or soil (65).

Heavy Metals, Essential Elements, and Health

As previously mentioned, coal ash contains a variety of toxic minerals and heavy metals. In the past few decades, a growing body of literature has reported an association between excess heavy metal body burden and neurological impairment and adverse changes in emotion (66). One study by Bao et al. (2009) investigated the relationship between heavy metal exposure, including lead, cadmium, and zinc, and presence of behavioral problems as determined by the Child Behavior Checklist (CBCL) in school aged children (67). Measuring heavy metal exposure through hair, they found that log-transformed hair lead and zinc were significantly associated with all 8 subscales of the CBCL and that log-transformed cadmium was significantly associated with social problems, attention problems, and withdrawn/depressed problems. In addition to toxic heavy metals, several essential elements have been the focus of recent research for their role in anxiety and depression (68, 69). These include elements such as copper, manganese, iodine, selenium, and vanadium. The following section will describe heavy metals and essential elements that have been found in coal ash as well as their association with various adverse health outcomes.

Aluminum

Aluminum is the most abundant metallic element in the earth's crust (70). Aluminum, silver-white in color and lightweight, is used for many industrial purposes (70). For example, it is used in the production of airplanes, cans, foil, and roofing and siding on buildings. While small amounts of aluminum can be found naturally in food, main exposure comes from the use of aluminum salts as food additives (70). While trace amounts can be found in the body, aluminum has no clear biological role (71).

Increased concentrations of aluminum have been associated with neurological effects in both animal and human studies. Animal studies have shown an association between aluminum and neurochemical changes altering acetylcholine function (66). In humans, studies have reported associations between elevated aluminum concentrations in the brain and Alzheimer's disease (66).

Arsenic

Arsenic is a naturally occurring element found all over the world (72). Unfortunately, most forms of arsenic are toxic (72). Human exposure mainly comes from food sources such as rice, grains, vegetables, and fruits that have absorbed arsenic through water or soil (72). Despite this, there are no recommended dietary allowances for arsenic due to a lack of data for adverse effects (73). Arsenic has no biological function in the human body (73).

Arsenic, according to the International Agency for Research on Cancer (IRAC), is a human carcinogen (44). The EPA categorized inorganic arsenic that is orally ingested as a group A carcinogen; meaning that there is enough evidence to support a causal relationship between arsenic and human cancer (44). One notable study examined the association between arsenic as a by-product of coal combustion and cancer risk. The Exposure to Arsenic and Cancer Risk in Central and East Europe (EXPASCAN), funded by the European Union in 1999, was a population-based case-control study that aimed to estimate the risk of environmental arsenic exposure from a coal-fired power plant on the development of non-melanoma skin cancer (NMSC) in the District of Prievidza, Slovakia (44). Two exposure variables accounting for annual emissions and residential history were created. The first exposure variable took into account the distance from the residence to the plant, where as the second variable also considered workplace location. Investigators reported the odds ratios (OR) for NMSC were 1.90 (95% CI: 1.38-2.62) and 1.90 (95% CI: 1.39-2.60), respectively, for the highest exposure compared to the lowest exposure (90^{th} percentile vs. 30^{th} percentile). These models controlled for both age and gender. Controlling for non-environmental arsenic exposure, this study concluded that there was a significantly increased NMSC risk among this population.

Chromium

Chromium is naturally present in soil and rocks but can also be found in plants and animals (74). Chromium is present in three forms (0, III, VI) and is used to manufacture several products including stainless steel cookware, tanned leathers, and treated wood. Chromium (III) is needed by the body in trace amounts. The adequate intake for chromium in children is as follows: 15 mg/d for ages 4-8 years, 25 mg/d for males 9-13 years of age, 35 mg/d for males 14-18 years of age, 21 mg/d for females 9-13 years of age, and 24 mg/d for females 14-18 years of age (73). Chromium works to maintain normal blood glucose levels in the body.

Excess chromium exposure, particularly exposure to chromium (VI), can lead to adverse health outcomes. For example, chromium (VI) is carcinogenic to human health; research has identified it as a known cause of lung cancer (74). Furthermore, studies suggest that exposure through drinking water increases the risk for stomach tumors (74). Rosa et al. (2016) investigated the effects of ambient chromium exposure from ferroalloy production and determined that it was positively associated with increased risk for asthma among adolescents (RR=1.08, 95% CI: 1.06-1.11) (75).

Copper

Copper is naturally found in the earth's crust. This ubiquitous mineral is an essential to all living organisms because it is a key component of cytochrome c oxidase, which is a respiratory enzyme complex vital for aerobic respiration (76). As a trace element, copper is found in a variety of plant and animal sources. These include beans, peas, nuts, and meat (77). In 1982, the WHO published its evaluation on copper stating that it was neither carcinogenic nor appeared to be a cumulative toxin hazard to humans, with an exception to the latter being persons with Wilson's disease (78). Recommended dietary allowances suggest that children between the ages of 4-8 years consume 440 µg/d, 9-13 years consume 700 µg/d, and 14-18 years consume 890 µg/d (73). In addition to its role as an essential trace element, this soft and malleable reddish-orange metal has advantageous thermal and electrical properties. Its ability to conduct both heat and electricity has led to the utilization of copper as building material, which can serve as a source of exposure.

Though copper is an essential element required by the body in trace amounts, copper imbalance, either too little or too much, has been shown to be associated with adverse health outcomes (79). When the body is copper deficient, the central nervous system can be affected (66). Studies that focus on tissue mineral analysis have reported associations between low copper levels in tissue and patients with Parkinson's disease and multiple sclerosis (80). Menke's disease is a hereditary condition that inhibits copper metabolism and results in copper deficiency. It is largely characterized by an abnormally developed central nervous system and can lead to psychomotor disturbances, seizures, mental impairment, and even death (66). On the other side of the spectrum, Wilson's disease is associated with excess accumulation of copper in the body. The copper toxicity caused by this condition can result in disturbances in coordination, tremors, and severe psychiatric disorders (81).

Iron

Iron is an important essential mineral required by the body (82, 83). It is naturally available in a variety of food sources as heme and non-heme iron; heme iron is readily absorbed by the body whereas non-heme iron has to undergo a reduction process before it can be absorbed (84). Additionally, iron can be consumed from foods that have been fortified with iron and iron supplements. Food sources of iron include meat, poultry, fish, and a variety of plants (84, 85). The recommended dietary allowance for iron intake in children is as follows: 10 mg/d for ages 4-8 years, 8 mg/d for ages 9-13 years, 11 mg/d for males 14-18 years of age, and 15 mg/d for females 14-18 years of age (73). Iron plays a very important role in the human body; it is an essential component of hemoglobin and other enzymes required for a wide variety of metabolic processes. Nearly 67% of total body iron is used in hemoglobin production (82).

Similarly to copper, both too little and too much iron in the body can have negative impacts. Iron deficiency has been associated with cognitive function and attention deficit (66). The central nervous system is also affected by the presence of excess iron; increased iron concentrations in the brain have been associated in the pathogenesis of Parkinson's disease (66).

Lead

Lead is a naturally occurring element that is found in the Earth's crust, therefore it is can be found in the soil, dust, air, and water (65). Industrially, lead has many uses; it has been used to make batteries, ammunition, paint, and piping. Lead can be released into the environment throughout the usage lifecycle, from mining to recycling. Due to its widespread use, environmental lead exposure has become a prominent public health concern particularly in young children (65). In 1978, lead was officially banned as a paint additive in the United States, however the majority of residential buildings built prior to 1980 used lead based paint (86). In children with high lead levels, the home environment is often a major contributor to source exposure due to dust particles and chipped paint contaminated by lead (65). Though some children have detectable lead levels, it has no biological role in the human body.

Adverse effects of excess body burdens of lead are well established. Lead exposure can affect several organ systems such as the central nervous system, cardiovascular system, and renal system (87). Lead toxicity can be accompanied by symptoms that include irritability, fatigue, muscle weakness, stomach pain, and anorexia

(66). Specific symptoms in children include speech abnormalities, loss of control of bodily movements, brain impairment, seizures, and coma (66). Several studies that examined effects of occupational lead exposure found that excess exposure was linked to depression, psychomotor impairment, memory impairment, and hostility (88, 89). In addition to excess lead levels, even chronic low levels in children have the potential to impact health. For example, low lead levels are reportedly associated with motor coordination problems and spatial integration, learning disabilities, hyperactivity, aggressiveness, and distractibility (66, 90).

Manganese

Like copper and iron, manganese is an essential element in the body (69). It can be found in food, water, and air and is absorbed through the gastrointestinal tract or through inhalation. Foods with the highest amounts of manganese include nuts, ready to eat cereals, beans, and peas (77). The adequate intake levels of manganese for children is 1.5 mg/d for children 4-8 years of age, 1.9 mg/d for males 9-13 years of age, 2.2 mg/d for males 14-18 years of age, and 1.6 mg/d for females 9-18 years of age (73). As an essential element, manganese plays a large role in the function of the central nervous system (91).

Adverse outcomes of excessive levels of manganese in the body have long been established. Excess exposure can lead to manganism, a term used to describe manganese poisoning (92). Occupational studies found that excessive exposure to airborne manganese could lead to both motor and cognitive deficits, causing parkinsonian-like disease (91). More recently, findings from a study conducted in Brazil examining behavior traits in school-aged children exposed to airborne manganese were published in several research articles (93-95). Investigators found that children with elevated airborne manganese levels had significantly increased inattention and externalizing behaviors (93). These findings were more pronounced in females when compared to males. Additionally, investigators reported positive associations between airborne manganese exposure and lower neuropsychological performance of executive function, IQ, verbal working memory, and strategic visual formation (94).

In addition to movement disorders and cognitive ability, occupational exposure to manganese in dust and fumes has been an identified risk factor for decreased psychiatric health (91). A community study in Marietta, Ohio aimed to assess this outside of an occupational study (91). Marietta is home to Eramet Marietta, Inc., which is one of the leading producers of ferro- and silicomanganese in the United States. The surrounding community, which is exposed to the elevated airborne manganese released from the plant, was compared to the demographically similar community of Mount Vernon, Ohio. Investigators reported that the manganese-exposed group had significantly higher generalized anxiety scores than did the comparison group, as determined by the Symptom Checklist-90-Revised test. The study also tested for significant differences in neurological test scores, and found no difference between the two towns. Therefore, it is still unknown whether the association of environmental manganese exposure is due to neurotoxic effects or mere concern about potential health effects. This study highlights the need for similar, more conclusive studies that examine environmental metal exposure and mental health.

Nickel

The Earth's core is composed of 6% nickel, which is the 24th most abundant element (96). It is commonly found in soil and can be released by volcanoes. In pure form, nickel is a solid, silvery-white metal (96). It is often combined with other metals, such as copper, iron, zinc, and chromium, to form alloys. It is used to make jewelry, coins, batteries, heat exchangers, and most commonly stainless steel (96). Certain foods, such as nuts, cereals, sweeteners, and chocolate, contain trace amounts of nickel that can then be introduced into the body. There are currently no recommended dietary allowances or adequate intakes available for nickel at any age (73). Nickel has no clear biological purpose in humans.

Excess nickel exposure, especially in occupational settings, has been studied at length. It is a known risk factor for several adverse health outcomes including lung and nasal cancer (97, 98). More recent studies have focused on investigating ambient nickel exposure and adverse health outcomes in the community. In a study in adolescents examining ambient metal exposure from ferroalloy production, researchers reported a relative risk for asthma as 1.11 (95% CI: 1.03-1.21) when the nickel concentration increased 4 ng/m^3 (75). Authors also reported that nickel was associated with an increase in the use of asthma medication in the previous year (RR=1.13, 95% CI: 1.01-1.27).

Titanium

Titanium makes up approximately 0.6% of the Earth's crust and ranks fourth among the most abundant structural metals, placing behind aluminum, iron, and magnesium (99). Titanium boasts the highest strength to density ratio, but due to its high costs compared to other similar metals it tends to be utilized sparingly (99). Several industrial applications use titanium, such as in aero engineering, building materials, and high performance cars (99). It is also optimal in the biomedical field, as titanium is used for implant material. Other consumer products that contain titanium include watches, jewelry, cameras, and sporting goods such as golf clubs and bicycles. Titanium dioxide is a naturally occurring form of titanium and used in a wide array of every day consumer products (100). For example, it is a common additive to food products such as chewing gum and candy (100). While trace amounts can be found in the body, titanium does not play role in any known biological process (100).

Titanium dioxide cannot only be found in many consumer products, nanoparticles of titanium dioxide are commonly found in fly ash samples (101). These particles typically range from 0.1-5 nanometers in size (101). Unfortunately, research investing potential health effects from exposure is limited. Several recent studies, both in vivo and in vitro, have investigated the role of titanium dioxide nanoparticles in inflammation and oxidative stress (102-105). Bhattacharya et al. (2009), using a human lung in vitro study, showed that titanium dioxide produced increased free radicals and indirectly induces DNA-adduct formation. Hanot-Roy et al. (2016) investigated the role of titanium dioxide on alveolo-capillary barrier cell lines. The study reported that that titanium dioxide nanoparticles induced oxidative stress, which resulted in DNA damage. These studies suggest that there are likely adverse health effects from exposure to titanium oxide nanoparticles.

Zinc

Zinc is largely extracted from zinc sulfide ores for industrial use, as elemental zinc is only found sparingly in nature (106). Zinc has several advantageous industrial applications and uses which span from being used to make coin currency in the United States to being utilized for medicinal purposes (106, 107). There are several routes from which people can be exposed to zinc, many of which result from anthropogenic means. Exposure routes include air, soil, water, and food sources. Coal combustion can affect the amount of zinc released into the air, soil, and water (106). Fugitive dust containing zinc can contribute to increases of the zinc concentration in ambient air. Furthermore, fly ash placed in landfills or ash ponds may lead to zinc being released into the soil (106). As zinc-containing soil erodes, it can leach into water sources. Meat, poultry, seafood, whole grains, nuts, and some dairy products are among food sources that contain zinc (106, 107). In the United States, the recommended dietary intake for children 7 months to 3 years is 3 mg/d, children 4-8 years 5 mg/d, children 9-13 years 8 mg/d, males 14-18 11 mg/d, and females 14-18 years 9 mg/d (107).

Zinc is an essential element in the body and is involved cellular processes. As a co-factor for enzymes, zinc plays a role in DNA synthesis, brain development, bone formation, normal growth, wound healing, reproduction, and behavioral response (106). Both too little and too much zinc can cause adverse health outcomes. While zinc isn't as toxic as other metals like arsenic or lead, too much zinc in the body can lead to gastroenteritis like symptoms (106, 107). Chronic zinc exposure has been associated with impaired copper absorption and anemia (107). Zinc deficiency has been linked to appetite loss, weight loss, alterations of taste, growth retardation, and inhibited immune function (106, 107). Zinc deficiency is also being explored as a potential contributor to maternal and pediatric mental health problems. Animal studies have shown associations between zinc deficiency and depressive behaviors like decreased activity and lethargy

(108). Several human studies have shown that patients diagnosed with depression have lower serum or plasma zinc concentrations, but whether low zinc levels are a cause or an effect of depression still remains to be determined (108). While some research may suggest that low zinc levels are associated with depression, as previously mentioned, Bao et al (2009) reported significant associations with elevated zinc exposure and the withdrawn/depressed subscale of the CBCL. The relationship between zinc and emotional problems remains unclear.

Metals, Oxidative Stress, and Mental Health

The pathophysiology for both anxiety and depression are still largely unknown. Several etiological theories have emerged over the years, including a new theory which involves the role of oxidative stress in the etiology of both anxiety and depressive disorders (109). Oxidative stress refers to the imbalance between antioxidants and oxidant homeostasis. This imbalance can occur when there are decreased levels of antioxidants, there is an increased production of oxidants, or when both phenomena occur simultaneously (110). For several reasons, the brain is thought to be particularly sensitive to oxidative stress (109). Some neurotransmitters in the brain can act as reducing agents. The brain is abundant in ions, such as copper and iron, that catalyze free radical reactions and lipid substrates used in oxidation (109). Additionally, the brain produces a large amount of free radical by-products because it consumes a large proportion of the body's oxygen. Oxidative stress has been implicated in many neurodegenerative and psychiatric disorders (109).

Robust research has documented the role of both reduction-oxidation (redox) active and redox inactive metals in oxidative stress (111-116). Redox active metals, such as chromium, copper, and iron, are capable of undergoing redox cycling. This process leads to the production of superoxide (O2-), a reactive oxygen species (ROS). Redox inactive metals, such as cadmium, lead, and mercury, deplete thiol-containing antioxidants and enzymes. Ultimately, both redox active and inactive metals can elevate ROS production which inhibits cells antioxidant mechanism leading to oxidative stress (111).

Oxidative stress has been linked to several neurodegenerative disorders and more recently it has been linked to psychiatric disorders including anxiety and depression (109, 110, 117, 118). One of the first epidemiological studies on the topic conducted by Matsushita et al. (2010) examined associations between anxiety and serum antioxidative and oxidative levels in college students. Authors reported that there were significant associations found between elevated anxiety and increased reactive oxygen metabolites among female participants, but not among male participants (118). Guney et al. (2014) published results from the first study to examine the effect of oxidative stress on anxiety in children. Authors found that children with anxiety disorders had higher levels of both total oxidative status and oxidative stress index when compared to age- and gender-matched healthy controls (110).

There is a rapidly growing body of research in regards to depression and oxidative stress over the past decade. A meta-analysis conducted by Liu et al. (2015) concluded that when compared to controls depressed subjects had lower levels of serum total antioxidant capacity (TAC), antioxidants, and paraoxonase (119). Furthermore, depressed subjects had higher levels of oxidative damage and serum free radicals. Similarly, another meta-analysis by Black et al. (2015) found that oxidative stress when measured by 8-hydroxy-2'-deoxyguanosine and F2-isoprostanes was elevated among depressed subjects (120).

Anxiety

Feeling anxious can be a normal part of everyday life. An anxious reaction to a stimuli, such as a perceived danger or high stress event, can be adaptively advantageous (121). However, one may have an anxiety disorder if an anxious feeling involves more than experiencing occasional worry and it persists for an excessive amount of time, or is a reaction to irrational fear (121, 122). An estimated 8-12% of children meet the criteria for an anxiety disorder severe enough to impact day-to-day life, making anxiety disorders one of the most common types of mental illness in children (123). Generalized anxiety, obsessive-compulsive disorder, panic disorder, separation anxiety, and social phobia represent the various forms of child anxiety disorders. Each of these disorders can cause adverse academic and social outcomes with effects that can permeate into adulthood. For example, several studies hypothesize that anxiety disorders in children are not transient over time, rather the disorder may persevere into adulthood if left untreated (124). For these reasons, identifying clinically diagnosable children, exploring potential risk factors, and finding effective treatment are important public health tasks.

Pathological anxiety is characterized by an exaggerated state of avoidance and anxiety caused by distress (125). In children, normal and pathological anxiety is particularly difficult to differentiate between for several reasons. Throughout normal development, children exhibit transient anxieties and fears. For example, separation from a primary caregiver is common between 12 and 18 months of age. Additionally, young children may not be able to accurately communicate thought processes, perceptions, emotions, and avoidance of certain circumstances, not to mention the associated distress, making diagnostic classification systems hard to use.

Commonly utilized diagnostic systems include the International Classification of Diseases (ICD, version 10) developed by the World Health Organization and the Diagnostic Manual of Mental Disorders (DSM-IV) developed by the American Psychiatric Association (125). Over the past 20 years, conducting standardized questionnaires and interviews specifically developed for the use in children has positively impacted the validity and reliability of anxiety disorder diagnoses (125).

At the turn of the 21st century, childhood mental illness disorders gained attention in the media which stemmed a reaction from the research community (126). Before this time, there was little empirical evidence to describe the size of the problem in the United States. The National Institute of Mental Health (NIMH) and the National Health and Nutrition Examination Survey (NHANES) started a collaboration to address this issue. From 2001-2004, NHANES collected the first nationally representative sample of aggregate prevalence on certain mental health disorders in children from 8 to 15 years of age. Merikangas et al. (2010) reported these findings. Investigators found that the 12-month prevalence rate of generalized anxiety and panic disorders, as determined by DSM-IV criteria, was 0.7%. Additionally, adolescents with higher poverty index ratio scores (PIR) were more likely to report anxiety disorders when compared to children with lower poverty index ratio scores. Study results showed a significant correlation between anxiety and mood disorders (OR=29.5, 95% CI: 9.4-92.3). Furthermore, children with high levels of anxiety could be at a higher risk for depression in adulthood (127).

While the previous report was the first to assess several mental health disorders in children in a population-based study, it is likely that the reported estimates of anxiety disorders are low because they only assessed generalized anxiety and panic disorders. Several community-based studies have reported slightly higher estimates. A study by Costello et al. (2004) indicated that one in three to four children meet the criteria for a mental disorder as defined by the DSM measures. Of these, only a small portion, approximately 10%, have severe impairment or distress that drastically impacts the child's academic, social, and emotion function (128).

Several studies have sought to identify risk factors associated with anxiety disorders. However, it has proven difficult to determine if a proposed risk factor preceded the disorder (125). Furthermore, demonstrating an association between the probability of an anxiety disorder and the frequency, severity, or duration of a given risk factor is challenging. Cross-sectional studies have been used to generate hypotheses on certain potential risk factors such as environmental factors, hereditary factors, and demographics variables. These hypotheses are then studied through prospective-longitudinal studies.

When considering risk factors for childhood anxiety disorders, demographic variables of interest include gender, education of the child, and socioeconomic status. The literature has consistently shown that females have a higher risk of developing any anxiety disorder when compared to males; females are about two times more likely to develop an anxiety disorder (125). Furthermore, research has shown that this gap increases with age. One study by Wittchen et al. (1998) that examined prevalence of mental disorders and impairment in adolescents and young adults found higher rates among those with lower educational attainment when compared to those participants with higher educational attainment (129). A point of caution should be made, however. Anxiety disorders are known to cause education impairment therefore it is difficult to determine when education would be a predictor or consequence of an anxiety disorder (125). Socioeconomic status has also been associated with anxiety disorders. While it is unclear if socioeconomic status plays the role of a mediator in a larger, more complex relationship with anxiety disorders, several cross-sectional studies have noted an inverse association with lower income levels and higher risk for anxiety disorders (125). Therefore, it is important to consider in future research.

Familial and environmental risk factors have also been identified through various epidemiological studies. Both family and twin studies have shown that all anxiety disorders have familial aggregation (125). Generally, when a parent has a least one anxiety disorder the child has an increased risk for developing an anxiety disorder. Additional risk occurs when both parents suffer from one or more anxiety disorders. Twin studies, which are more capable of untangling the genetic association with associations due to a shared environment than classic family studies, have estimated that the total proportion of genetic variance, or rather heritability, accounted for 25-35% (130). This suggests that environmental factors play a large role in total variance. Furthermore, that non-shared environment plays a larger role than shared environment.

Both homotypic and heterotypic comorbidities have been identified in children and adolescents with anxiety disorders (125). In respect to homotypic comorbidities, research had shown that the number of anxiety disorders could lead to secondary psychopathological developments. One study by Woodward and Fergusson (2001) followed a birth cohort including 1265 children from New Zealand for 21 years found that the number of anxiety disorders reported in adolescents were significantly associated with increased risk of developing anxiety disorders later in life (131). Other known comorbidities include substance abuse or dependence, suicidal behavior, lower educational attainment, early parenthood, and major depression. Substance abuse or dependence has been widely identified as a common comorbidity with externalizing behaviors (125). However, research now suggests that substance use could be a coping mechanism for those suffering with anxiety and this use might lead to secondary long-term dependence (132). While the pathological mechanism largely still remains a mystery, anxiety disorders have been strongly associated with an increased risk for secondary depression (125). This has been investigated by cross-sectional studies and longitudinal studies, in which general anxiety and specific anxiety disorders increase the risk for later development of a depression disorder (131, 133-136). The severity of the anxiety disorder and the number of anxiety disorders one suffers from can both affect the risk of depression onset.

The area of child anxiety disorders can be a difficult topic to research (125). Younger children are not equipped to communicate in depth with diagnosticians or clinicians about distress or impairment they may experience, making it difficult to properly diagnose (125). Furthermore, identifying risk factors for child anxiety disorders can be difficult to determine which came first. For example, scholarly distress is thought to be a risk factor however it is also a consequence of child anxiety disorders. Much of the current literature focuses on risk factors that occur during childhood and their association with anxiety disorders in adulthood. This is of concern because child and adult anxiety disorders are not the same. More research with an emphasis on child anxiety disorders is needed to help discover and understand the main risk factors (125).

Depression

Depression is a fairly common mood disorder that can affect many aspects of everyday life. While most people experience short-lived bouts of the blues, to be diagnosed with depression the symptoms must persist for two weeks or more (127). In recent reports, major depressive disorder in children has been found to range from 0.2% to 17%, while the median is about 4% (128). Many of those who have a depressive disorder or clinical depression need treatment. Depression may persist into adulthood if children go untreated. Therefore, it is important to identify vulnerable populations, identify the risks associated with depression, properly diagnose children, and provide appropriate treatment.

Depression is characterized by several signs and symptoms. While the canonical symptom is sadness, not all people with depression feel sad (127). Those suffering from depression often experience decreased energy and fatigue; difficulty sleeping or oversleeping; appetite changes; restlessness and irritability (127). They may also have difficulty making decisions, remembering, and concentrating; a persistent anxious, sad, or empty mood; feelings of guilt, helplessness, hopelessness, worthlessness, and/or pessimism; loss of pleasure or interest from activities and hobbies (127). It is important to note that not all people with depression will experience all symptoms. The frequency, duration, and severity of the symptoms depend on the individual and type of depression from which they are suffering. Depression in children can look slightly different. For example, children who are depressed may refuse to go to school, fake illness, be clingy towards a parent, or have irrational fears that a parent might die (127). Similarly to pediatric anxiety, normal behavior in children is relative to their stage of development, which can make it difficult to decipher whether the child is depressed or going through a temporary phase of development.

The average onset of depressive disorders and major depressive disorders in children is between 11 and 14 years of age (128). Older adolescents have higher rates of mood disorders when compared to their younger counterparts (126). Unlike child anxiety disorders, there is no gender gap in the risk for depressive disorders in preadolescent children (128). However, during adolescence gender differences do become apparent; females have higher rates of depressive disorders than do males. While some adult studies have found an association between depressive disorders and socioeconomic status, the findings for child depressive disorders is unclear (128). Race is also an important consideration. A growing body of literature has examined the rates of depressive disorders among different racial groups and evidence suggests that Hispanic youths have higher rates when compared to white and African-American children (128). Research also suggests that African-American children have lower rates than their white or Latino counterparts.

Maternal depression is another important risk factor in pediatric depression. Maternal depression has been associated with a wide range of poor child emotional and behavioral outcomes including mood disorders and other internalizing behaviors (137). Unfortunately, little is known on the strength of associations between maternal depression and these different child psychopathologies (137). Furthermore, covariates that might modify this relationship need to be identified in order to shed light on these associations. Maternal depression has also been related to family dysfunction, marital issues, and paternal adverse mental health outcomes (138). Maternal depression seemingly plays a large role in family functioning and child development.

Depressive disorders are a well-established comorbidity of several anxiety disorders (125). As previously mentioned, Merikangas et al. (2010) found a striking correlation between mood and anxiety disorders in their population-based study; the reported odds ratio was 29.5 (95% CI: 9.4-92.3). In fact, the co-diagnosis of anxiety and depressive disorders is so common that new research hypothesizes that anxiety disorders may be involved in the development process of depression; the expression of anxiety is a precursor to the later developed depression (128).

Like anxiety, definitively establishing risk factors for pediatric depression is difficult because it can be hard to decipher whether the proposed risk factor actually preceded depression or results from depression. Child mood disorders, like anxiety and depression, affects an estimated 8-17% of the population (125, 128). More research is needed in this area to provide a better understanding of the burden of disease and to identify plausible risk factors that could be incorporated into intervention methods.

Measures of Anxiety and Depression in Children

Child behavioral and emotional issues, like attention-deficit/hyperactivity disorder or depression, have been studied in a variety of contexts throughout the years triggering the need for quick assessment tools. Several standardized parent-report questionnaires have been developed to measure and categorize behavioral and emotional problems in children (139). These particular types of questionnaires are completed from the parent or caregiver's perspective, as they see the child on a day-to-day basis. In addition to providing valuable information, parent-report questionnaires require little time from the researcher or physician and cost very little, making them ideal assessment tools.

The Child Behavior Checklist was developed in 1983 by Thomas M. Achenbach (140). Since then, it has become one of the most widely used tools to assess behavioral and emotional problems in children. The CBCL has undergone several revisions over the last 30 years, its latest version assesses externalizing and internalizing behaviors based on the DSM-oriented scales as well as syndrome scales. Researchers have utilized the CBCL for studies examining behavioral problems such as ADHD and aggression (93, 141, 142). It has also been used to assess emotional problems such as anxiety and depression (143-145).

Gaps in the Literature

In the last several decades, the use of coal has become more prevalent, in turn increasing the amount of coal being mined around the United States. Several studies have investigated the health effects and social injustices in coal mining communities (47, 146). The majority of available studies have centered on the occupational health hazards associated with coal mining and combustion. As a consequence of increased coal mining and combustion efforts, coal ash is increasing and its effects on health are of growing concern. Studies that address coal ash and its impact on physical, mental, and social well-being in the surrounding communities are few and far between. It is likely that the residuals of coal combustion have serious implications in the surrounding communities. Furthermore, because children are still developing both physically and neurologically they are more susceptible to potential harms of CCR and more vulnerable to the excess exposure of heavy metals and essential elements found in coal ash. The overall study and the current study are some of the first research projects designed to address this gap in the literature. This sub-study is one of the first to look solely at the mental health aspect in children as related to exposure to fly ash, metals, and ambient air pollution.

METHODS

The current study is part of a much larger, overarching study entitled "Coal Ash and Neurobehavioral Symptoms in Children Aged 6-14 Years Old." The 5-year study is funded by the National Institute of Health (NIH), National Institute of Environmental Health Sciences (NIEHS): grant number R01ES024757. The main study, conducted by Dr. Kristina Zierold, seeks to "(1) characterize indoor exposure from fly ash and heavy metals in homes of children residing near coal ash storage sites compared to children living further away from coal ash storage sites, (2) determine if the heavy metal body burden differs from children residing near coal ash storage sites compared to children living further away from storage sites, (3) assess if increased fly ash exposure and greater heavy metal body burden is associated with poorer neurobehavioral performance and more neurobehavioral symptoms, (4) utilize mapping, spatial analysis and modeling applications of geographic information systems (GIS) for household recruitment, analysis of distance decay effects, surface interpolation of Aims 1 and 2 results, and fate and transport modeling of fly ash."

Recruitment

In order to address the overarching research questions, 300 children are being recruited into the study. To assess the effects of distance, wind patterns, and multiple site exposures, the recruitment of participants was stratified into buffer zones and quadrats using ArcGIS software (147). Overall, there are five buffer zones spanning a 10-mile radius from a midpoint between the Cane Run generating station and the Mill Creek generating station; each of these zones reflects a 2-mile interval. These buffer zones are broken down further into four wedge-shaped quadrats; labeled A-D as seen in Figure 1. Each quadrat and corresponding buffer zone is used to designate a particular sampling unit. For example, sampling unit 1A refers to the population in the north/northeast quadrat 0-2 miles from the Cane Run generating station. There are a total of 20 sampling units. In order to take seasonality into account, five participants in each sampling unit for the four seasons (winter, spring, summer, and fall) are recruited during the 5-year study period.

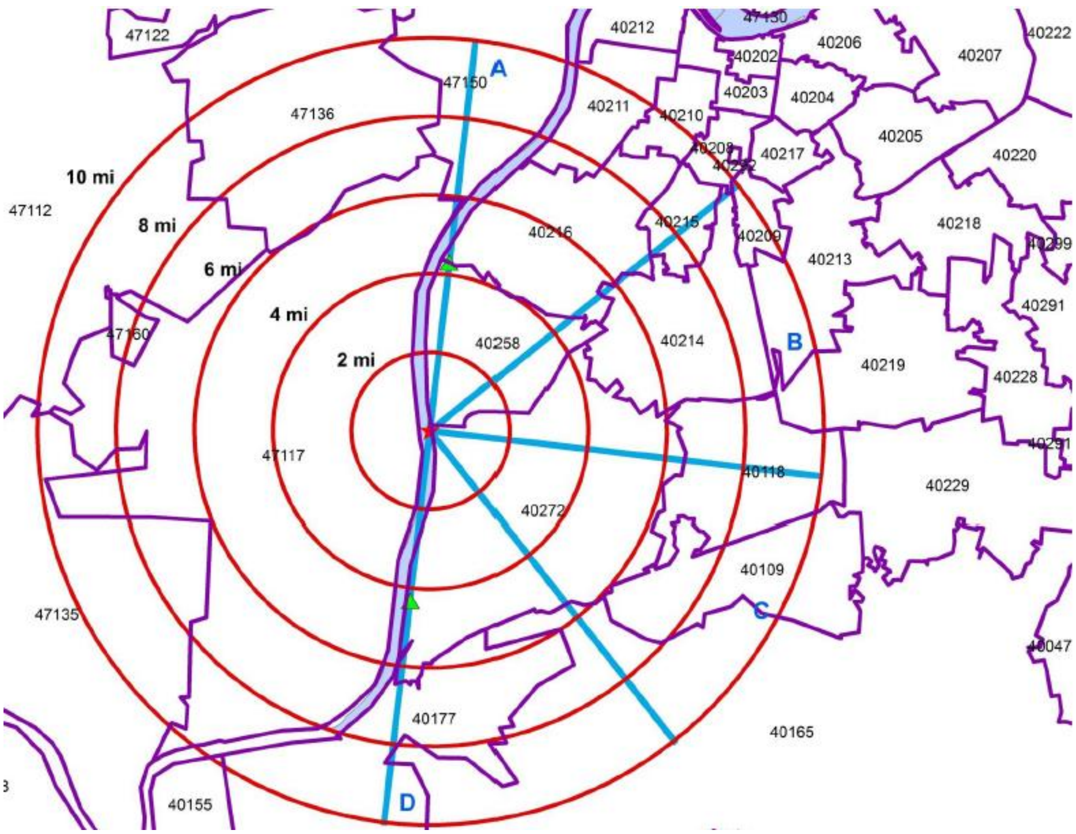

Figure 1. Recruitment Map Depicting Quadrats and Buffer Zones

Door-to-Door

Using the stratified recruitment map, study personnel began door-to-door recruitment in September 2015. When possible, study personnel briefly explained the study purpose to potential participants during door-to-door recruitment and left a flyer with further information. When residents were not home, flyers were left in visible locations that explained the study and provided contact information. Response rates ranged from 1% to 5% depending on the sampling area and the season; winter and summer months produced the lowest response rates.

Mailing List

In February 2016, the participant recruitment method incorporated a mailing list method to contact potential participants. The mailing lists purchased through LeadsPlease.com targeted families with children 7-15 years of age residing in the designated zip codes of the study. Recruitment materials included a letter explaining the study along with a flyer outlining the study purpose. Each set of mailings includes approximately 700-1000 addresses. The mailing list method yielded response rates similar to that of foot recruiting.

Study Population and Eligibility

Eligibility criterion included children between the ages 6 to 14 years who have lived in the study area for a minimum of two continuous years. Children with known genetic disorders associated with neurobehavioral problems were excluded. Additionally, parents who could not agree to smoke outside of the home for the week duration of air sampling were excluded from the study.

Informed Consent/Assent Documents

This study received approval from the University of Louisville Institutional Review Board (IRB 14.1069). Before participation in the study, study personnel explain two consent forms with the parent or guardian of the child and one assent form with the child participating in the study. Each of the subject informed consent and assent documents explain the participant's role in the study and highlights the potential risks, benefits, compensation, and confidentiality of the study. Furthermore, the informed consent documents explain that participation in the study is voluntary and provides the participant with contact information should they have questions or concerns about the study. Two copies of all documents are signed; one copy is kept by the study participants and one is kept by the researchers.

The first subject informed consent document pertains to the parent's participation in the study. By signing this form the parent agrees to comply with several study procedures including: 1) agree to allow the study team to set up air pollution samplers in their home, 2) agree not to smoke in the home two days before the sampling period began and during the duration of air pollution sampling, 3) agree to fill out an activity diary during the air pollution sampling period, 4) allow the study team to use lift tape to take environmental samples in the participating child's bedroom, 5) agree to help cut their child's toenails and fingernails, 6) allow the study team to conduct an environmental assessment of the home, 7) agree to have at least one parent present when the child completes the neurobehavioral tests and during the health assessment, 8) complete the Child Behavior Checklist, 9) complete the Environmental Health History questionnaire,

10) complete the Home Cleaning questionnaire, and 11) complete the Pediatric Health History interview.

In the second subject informed consent document, the parent consents to have their child participate in the study. This document explains the learning tests the child will complete, the nail collection process, and measurements collected by the study nurse. By signing the form, the parent agrees to let their child participate. Furthermore, the parent agrees to help cut the child's fingernails and toenails, in accordance with the instructional handout, and store the nails the provided plastic container.

Based on the child's age, <10 years or ≥ 10 years, the study personnel went over one of two possible assent forms with the child. Each form explains the child's role in the study: the learning tests, nail collection, and measurements collected by the study nurse. Additionally, the forms explain the risks of the study and the incentive for participating. Children <10 years received a toy valued at $25 while children 10 years and older chose to receive a $25 pre-paid gift card or toy from a toy list.

Exposure Assessment

There are several exposures of interest in this study. First, the concentration of PM_{10} in the participant's home environment was determined. Second, metal concentrations of aluminum, arsenic, chromium, copper, iron, manganese, nickel, titanium, and zinc in the home environment were determined. Additionally, this study examined effects of metal concentrations present in the child's body. Finally, the presence of absence of fly ash was determined. The exposure assessment methods are discussed below.

Outcome Measures

This section covers the outcome variable definitions that are used in each of the specific aims. T-scores from subsections of the Child Behavior Checklist (CBCL) are the main interests in this study. The outcome for subaims A used the t-scores from the Anxiety Problems DSM-oriented scale on the CBCL. The outcomes for subaims B and C used the t-scores from the Withdrawn/Depressed subscale and Anxious/Depressed subscale, respectively, of the internalizing behaviors scale of the CBCL. T-scores for each outcome, subaims A, B, and C, were then dichotomized. Since this research was interested in looking at anxiety and/or depression problems in children, normal t-scores from the CBCL were used as "non-diseased" (0=t-scores < 65) while borderline and clinically significant t-scores were grouped together (1=t-scores ≥ 65).

Filters

Sampling Train

This study utilizes AirChek XR5000 air sampling pumps, which are small, lightweight pumps specifically designed to provide accurate (± 5% of set-point) airflows between 1-5 L/min by using an isothermal closed loop flow sensor. The isothermal closed loop flow sensor directly measures and constantly maintains the set flow rate. To compensate for fluctuations in temperature after the pump has been calibrated, the AirChek XR5000 has a built in sensor. In the case of excessive backpressure, for example if the filter becomes overloaded, the AirChek XR5000 is designed to stop after >15 seconds. The pump will display a flow fault icon on the screen and attempt to restart up to five times every 15 seconds.

The XR5000 air pump is connected to a patented SKC single-stage Personal Modular Impactor (PMI, SKC Inc.), which is specifically designed to efficiently collect PM_{10}, via ¼ inch diameter plastic tubing. The impactor houses a 37 mm polycarbonate filter that collects the PM_{10} and a 25 mm pre-oiled disposable impaction disc, herein referred to as an oil substrate, which is inserted onto the top of the filter cassette. The oil substrate decreases particle bounce allowing for more efficient particle collection. For optimal impactor performance, the air sampling pump flow rate is set to 3.0 L/min.

Initial Flow Rate, Field Placement, and Final Flow Rate

Prior to placing the sampling train in the field, each pump is calibrated using a MesaLabs DryCal Defender 510 in the lab. After calibration, three flow rate readings are taken one minute apart and then recorded in the Flow Notebook. All readings are within ±5 % of 3 L/min. The initial flow rate is calculated by averaging these three readings.

After the consent process, the air sampling train is set up in the main living area of the participant's home. Using tripod stands, the impactor is placed roughly 3-4 feet off of the ground to emulate the breathing zone of an average child. Additionally, strategic placement of the sampling train avoids windows, doors to the outside, air vents, fireplaces, stoves, and electronic devices to avoid resuspension of particles. Once in place, the sampling train is turned on and continues to run in the participant's home for approximately one week. At the end of the air sampling period, three to four flow rate measurements are taken with the DryCal and recorded in the Flow Notebook. The average of these measurements is known as the final flow rate.

Gravimetric Analysis

To calculate the mass on a filter, gravimetric analysis is conducted. Prior to being inserted into the filter cassette of the impactor, each filter is weighed three times using a BM-20 analytical microbalance. The average of these measurements is known as the pre-weight. Additionally, the filter is weighed three times after being placed in the field. The average of these measurements is known as the post-weight. The mass on the filter is the difference between the post-weight and pre-weight, as seen in Equation 1.

$$Filter\ Mass = Post\ Weight - Pre\ Weight \tag{1}$$

Overall Flow Rate

Initial flow rate (Q_1) and final flow rate (Q_2) measurements are collected prior to and after the sampling period, respectively. The average of these two values is known as the overall flow rate (Q), as seen in Equation 2.

$$Q = \frac{(Q_1 + Q_2)}{2} \tag{2}$$

Concentration Determination

To calculate the concentration of PM_{10} on the filter, mass on the filter (m) and the overall flow rate of the pump (Q), derived in the previous section, are used.

The flow rate can be defined mathematically as volume (V) divided by time (t), as illustrated by Equation 3.

$$Q = \frac{V}{t} \tag{3}$$

If Equation 3 is rearranged, the volume can be defined as the product of the flow rate and time:

$$V = Qt \tag{4}$$

Concentration (C) is defined as mass divided by volume, as found in Equation 5.

$$C = \frac{m}{V} \tag{5}$$

Substituting Equation 4 into Equation 5, concentration can now be written as:

$$C = \frac{m}{Qt} \tag{6}$$

Calculating the mass concentration on the filters is a vital step in determining the elemental distribution in subsequent laboratory methods completed by Elemental Analysis Inc. These analytic methods are discussed below.

Proton Induced X-ray Emission Spectroscopy

Proton Induced X-ray Emission (PIXE) is an elemental analysis method in which energetic protons cause a target atom to emit X-rays (148). More specifically, the energetic protons transfer kinetic energy to the inner shell electrons of the target atom, forcing the electrons from the atom resulting in X-ray production (149). The X-ray spectrum and energies are unique to the element from which they were emitted and the amount of X-rays emitted corresponds to the mass of the particular element being assessed in the sample (149). There are several advantages to PIXE analysis. First, because it is a non-destructive analysis method, errors from sample digestion and preparation are alleviated. Secondly, PIXE is capable of simultaneously analyzing 72 inorganic elements from sodium to uranium in liquid, solid, and aerosol filter samples. Additionally, previous studies have utilized PIXE, and other spectroscopic techniques, to conduct elemental analysis of coal and coal ash because it is effective in conducting elemental analysis of coal ash samples and offers a high level of precision (10). PIXE analysis will be used in this study to determine the elements and their concentrations in both air filter and nail samples.

Elemental Analysis Inc. in Lexington, Kentucky was contracted to conduct PIXE analysis for this study. The proton energy, which is measured in million electron volts (MeV), of the proton beam was calibrated to 3 MeV (148). The target samples were bombarded with proton beams carrying a proton current of 0.5 A. Low atomic numbered elements produce more X-rays per unit proton charge. This means that elements with lower atomic numbers have higher X-ray energy than elements with higher atomic numbers. To compensate for this phenomenon, each sample undergoes dual irradiation which creates uniform detection limits for elements across the periodic table, regardless of atomic number. In this context, dual irradiation means variation of irradiation times. X-rays emitted from the target are directly viewed in one position while an absorber, strategically placed between the detector and the sample, filters the emitted X-rays in the second position. The X-rays are them measured with a lithium-drifted silicon detector (149). This process makes it possible to detect limits for each of the 72 inorganic elements the PIXE analysis can detect; in both positions each element has a spectrum.

Similarly, standard calibrations are constructed. Each standard is irradiated once with a filter placed in front of the detector allowing preset charge collection and once without the filter. In the next step of the calibration process, the standards are fit into the gravimetric mass formula where X-ray line intensities for the standards are determined, recorded, and stored in a library. Next, using a least squares polynomial fit, calibration curves for each standard are created (10). Ultimately, each standard will have stored information on X-ray lines, intensities, and calibration curves representing the calibration for PIXE system. Thin targets, like the filters we are using in this study, are easily compared to the standard calibrations yielding PIXE analysis results.

Scanning Electron Microscopy with Energy Dispersive X-ray Spectroscopy

Scanning Electron Microscopy with Energy Dispersive X-ray Spectroscopy (SEM/EDX) is a quick, non-destructive surface analytical technique that creates high resolution images of surface topography (150). Primary electrons, produced from the scanning electron beam, bombard the sample's surface and in doing so generate secondary electrons. The secondary electron's low energy intensity is greatly affected by the surface topography of the sample. The surface image is generated by measuring the intensity of the secondary electron as a function of the scanning electron beam's position. Because of the primary electron beam's ability to focus on an area <10 nm in size, high resolution images are possible.

Primary electron bombardment from the scanning beam also creates backscattered electrons, which can be used to gather qualitative information on the elements in the sample (150). This can be accomplished because the backscatter electron intensity is associated with the atomic number of an element.

In addition to secondary and backscattered electrons, the scanning electron beam creates X-rays. As previously discussed in the PIXE section, X-rays are unique to the corresponding element. Therefore, analysis of the X-ray can provide semi-quantitative information on the elements in the sample (150). SEM/EDX analysis can be used to determine whether fly ash is present or absent on the filter and what elements are in the fly ash samples.

Nail Samples

Because fly ash is made up of several metals and metals are known to affect children's health and learning outcomes, this study examined the effects of metal body burdens in children. Toenail and fingernail analysis was used to assess this exposure. Collecting toenails and fingernails is advantageous in this study over other biological samples (e.g. hair samples, blood samples) for several reasons. First, because nail growth is slow it represents long-term exposure (151). While the actual exposure time period may be affected by age, gender, diet, or behaviors, nail samples usually include exposures from the previous 3-12 months (152). This is ideal as this study examines chronic exposure to coal ash and other metals. Second, nail samples are easily collected, stored, analyzed, and are non-invasive.

Sampling Process

For analysis, more than 150 mg of fingernails and toenails are collected from each participant. Each parent is provided a guide that explains how to cut nails and is asked to collect and store the nail samples in a clean plastic storage container. Due to different growth rates, this can take from three weeks up to several months to complete: on average, 4-6 clippings.

Cleaning Process and Final Weight

Before the final weight of the nail sample is recorded, each sample is cleaned. The cleaning process consists of an acetone rinse with agitation and two subsequent rinses with deionized water. The nails are then laid out to dry at room temperature before taking the final weight. The final weight is taken several days after the nails have been cleaned to allow time for the nails to thoroughly dry. The cleaning process is important because it removes any surface contamination and finger nail polish if present without altering the elemental content of the nail sample. Surface dirt and nail polish could ultimately affect the weight of the nail sample and show up in later analysis. Once the nails are cleaned, a final weight is taken using the BM-20 analytical microbalance. Finally, the nails are stored in a clean plastic container.

Nail Preparation and PIXE

The nail samples are then delivered to Elemental Analysis Inc. in Lexington, Kentucky where they undergo PIXE analysis. Before the nails can be analyzed, they are frozen and then pulverized. The pulverized nails are then mixed with a neutral binding agent called Somar-Mix Powder #210, a mixture of boric acid and water. The nail mixture is then pelletized into 5/8th inch diameter pellets that undergo PIXE, described in a previous section, to identify elements and their mass in the sample. Ultimately, elemental concentrations are determined.

Neurobehavioral Assessment

Child Behavior Checklist

While there are several instruments available that assess problem behaviors in children, the CBCL is among the most respected and widely used; it has been translated into over 90 languages (153, 154). Though there are CBCL forms available for different age groups, this study focuses on the CBCL for ages 6-18 years of age. Additionally, there are parent, teacher, and child report forms. For this study, the parent-report form was utilized. The CBCL parent questionnaire includes two sections. The first part of the questionnaire focuses on competence items to assess the child's social relations, activities, and school functioning (139). The second part consists of 113 statements that measure the type and scope several emotional and behavioral problems in children. The statements are scored based on a 3-point (0-2) ordinal scale, which indicates the frequency of the behaviors.

The CBCL scores are broken down in several ways. First, the CBCL's questions are associated with problems on a syndrome scale in eight different categories: anxious/depressed, withdrawn/depressed, somatic complaints, social problems, thought problems, attention problems, rule-breaking behavior, and aggressive behavior. Furthermore, anxious/depressed, withdrawn/depressed, and somatic complaints are broadly categorized as internalizing behaviors. Rule-breaking behaviors and aggressive behaviors are broadly categorized as externalizing behaviors. Overall, the CBCL yields scores for internalizing and externalizing behaviors, total problems, and six DSM-oriented subscales. The six DSM-oriented subscales include attention deficit/hyperactivity problems, anxiety problems, oppositional defiant problems, affective problems, conduct problems, and somatic problems (155). Based on age and sex, these scores are compared to clinical cut off points for the particular comparison group.

DSM-oriented scales (top-down model) use prevailing diagnoses to partition children's problems (156). The DSM-oriented scale for anxiety problems is used in this study as a primary outcome measure. Additionally, this study will measure anxiety and/or depression using subscales of the internalizing behaviors scale, as internalizing behavior classifications determined from the CBCL are widely used throughout the literature. Psychometric properties of the CBCL have been widely tested and published (157). The anxious/depressed subscale of the CBCL, which is made up of 13 questions assessing symptomatology of anxious and depressive problems, has a reported retest reliability of r=0.86 and a reported inter-rater reliability of r=0.77 (158). In a study by Read et al. (2015), the Cronbach's alpha when testing the internal consistency of the anxious/depressed subscale was 0.83. Furthermore, this scale has proven to accurately discriminate between youth with and without anxiety disorders and youth with and without depressive disorders (158). Lastly, Ebesutani et al. (2009) demonstrated that the withdrawn/depressed subscale of the CBCL was able to significantly discriminate between youths with major depressive disorder and dysthymic disorders.

The DSM-oriented anxiety problems subscale is made up of 6 questions assessing symptomatology of a range of anxiety disorders including generalized anxiety disorder, separation anxiety disorder, and specific phobia (158). Similar to the anxious/depressed subscale, the anxiety problems subscale has proven good retest reliability. Moreover, research published from Nakamura et al. (2009) indicates that all of the CBCL DSM-oriented scales accurately discriminate between youth with and without defined DSM nosologies (140). Read et al. (2015) reported the internal consistency, Cronbach's alpha, as 0.67 and concurrent validity for this subscale has ranged from fair to good in the literature (158).

Structured Clinical Interview

Structured Clinical Interviews for the Diagnosis of DSM Disorders (SCID) are follow up interviews completed to further evaluate children with t-scores that fall in the borderline or clinically significant range. A co-investigator and trained child psychologist completes the interviews. The interviews are conducted using the MINI-KID International Neuropsychiatric Interview for Children and Adolescents, version 6.0. The MINI-KID was specifically developed to provide psychiatric disorder diagnoses in youth accurately and reliably, requiring less time and training than other available structured interview diagnostics (159).

Study Questionnaires and Considered Covariates

Environmental Health History

The Environmental Health History Questionnaire (EHHQ) is a comprehensive survey that provides information on the child's exposure history that supplements biological measurements provided by nail samples and exposures determined by the air sampling. Currently, a validated questionnaire that assesses specific areas of interest in this study does not exist. Therefore, a comprehensive questionnaire was developed by the principal investigator of the study using the Pediatric Environmental History survey, the Agency for Toxic Substances and Disease Registry's "Taking an Exposure History", and the rapid questionnaire of environmental exposures to pregnant women as guides. The questionnaire is comprised of multiple-choice answers and no/yes choice answers. In addition to taking residential history, the questionnaire includes sections which assess 1) the child's demographic information and home characteristics, 2) child behaviors, 3) cleaning methods and supplies, 4) pesticides, insecticides, herbicides, 5) food and water, 6) hobbies done at the home, 7) occupations, 8) whether the child lives near hazardous sites, 9) questions about pregnancy, and 10) information about other places the child spends time.

Variables that are considered from the EHHQ include: age, gender, if anyone in the home smokes, frequency people smoke inside the home, and how frequently windows are kept open in the home.

Home Cleaning Questionnaire

The Home Cleaning Questionnaire (HCQ) is a very short survey designed to assess cleaning behaviors. The HCQ was developed by the principal investigator and includes nine multiple-choice questions. Several cleaning behaviors were investigated as potential covariates in this study. Cleaning behaviors were assessed by questions such as: how frequently do you clean your entire home, how frequently are wet methods used to clean your home, and how frequently are dry methods used to clean your home.

Health and Home Assessment

The child's health and home assessment, conducted by a trained registered nurse, is completed to compliment the EHHQ questionnaire in identifying additional potential confounders that should be considered in analyses. Working with the parents, the nurse completes a Pediatric Health History (PHH) form for each child participating in the study. This form collects extensive information on the child's health history as well as additional information on the parent's mental health, which is self-reported. The child's height, weight, and vital signs also are evaluated. In addition to collecting the PHH, the nurse does a visual inspection of the home utilizing the Pediatric Environmental Home Assessment (PEHA) survey, a publically available and standardized form created by the National Center for Healthy Housing. The PEHA is made up of multiple-choice selections and includes a visual assessment of the general housing characteristics, indoor pollutants, home environment, sleep environment, and home safety.

Variables from the PHH that were considered include: age, gender, race, ethnicity, height, weight, parent's marriage status, and both mom and dad's history of anxiety and/or depression. Data from the PEHA survey was unattainable for this study.

Socioeconomic Status

Socioeconomic status (SES) is an important covariate in many epidemiological studies. While the current study did not directly assess the SES of the participants through self-reported household income, the 2011-2015 American Community Survey (ACS) 5-Year Estimates was used to gather an indirect measure. Utilizing the American FactFinder advanced search tool, the census tract and block group was obtained for each participant's address. The address of participant 066 was not in the 2011-2015 ACS, likely because the home was built in 2012, therefore an address on the same street was used as a proxy to obtain the census tract and block group. The "median household income in the past 12 months (in 2015 inflation-adjusted dollars)" data set (ID=B19013) was accessed and the median household income by block group was recorded as the participant's SES measure. A categorical SES variable was created using this information, where 0=low income defined as participants with a household income ≤ $43,623, 1=middle income defined as participants with a household income between $43,623 and ≤ $52,822, and 2=high income defined as participants with a household income > $52,822.

Anxiety/Depression Medication

There are several different medications used to treat anxiety and/or depression in children. These medications include: fluoxetine commonly known as Prozac, sertraline commonly known as Zoloft, paroxetine commonly known as Paxil, citalopram commonly known as Celexa, escitalopram commonly known as Lexapro, and luvoxamine commonly known as Luvox (160). The listed medications were cross-referenced with the Pediatric Health History (PHH) questionnaire in order to create a dichotomized variable

(0=no medication used, 1=at least one medication used) that would control for anxiety/depression medication use in the analysis. However, only one participant reported use of any anxiety/depression medication: fluoxetine. That same participant also had clinical t-scores in the anxiety problems subscale and anxious/depressed subscale, as well as a borderline score in the withdrawn/depressed subscale of the CBCL. Therefore, this covariate was not used in the final analyses.

Statistical Analysis Overview

Statistical analyses were similar throughout all aims and therefore an overview of the statistical methods will be discussed together in this section. All statistical analyses were performed using SAS, version 9.4. Specific analyses will be discussed in subsequent sections.

Demographics Characteristics and Cleaning Behaviors

Certain demographic characteristics were assessed to evaluate differences by exposure and by outcome for each aim. Demographic characteristics included: gender, age category, race, SES category, parents' marriage status, smoking in the home, and frequency of smoking in the home. Additionally, self-reported anxiety and/or depression problems for the mother and the father of the participant were assessed by outcome. Cleaning behavior variables included: frequency the entire house was cleaned each week, frequency of wet and dry methods utilized to clean each week, and frequency windows were left open in the home. Demographic tables and cleaning behavior tables by outcome (anxiety problems, withdrawn/depressed problems, and anxious/depressed problems) and by exposure were constructed to describe the population used in Aims 1 and 2 and the population used in Aim 3. Statistical significance was calculated using

Chi-square p-values when the cell count was five or greater and the Fisher's Exact test p-values when the cell count was less than five. Variables that were significantly different by outcome or by exposure were considered further in subsequent analysis.

Purposeful Selection Model Building

The purposeful selection model building strategy was utilized to assess the relationship between each outcome and the various exposures of interest (161). There are several approaches to model building for logistic regression, however purposeful selection modeling is advantageous in epidemiological models because certain variables may not be statistically significant in the overall model but instead play critical roles in the relationship between the exposure and outcome of interest (161). There are several steps involved in purposeful selection model building, which seeks to create a model that strikes a balance between statistical significance, fitting the data well, and controlling for confounding variables. In the first step, a simple logistic regression model is fit for each variable of interest separately against the outcome. Next, those variables that have statistical significance at a liberal p-value threshold (p-value < 0.2) are kept for further evaluation. These variables are then added to a multiple logistic regression model against the outcome. Next, backwards elimination is used to remove variables from the model based on statistical significance (p-value <0.1) in a stepwise fashion. Covariates removed by backwards elimination are subsequently reconsidered for potential confounding effects with the remaining variables in the model. Variables that result in a 10% change of the odds ratio (OR) of the exposure of interest are re-inserted into the model. Finally, the model is assessed for the goodness of fit to the data.

Propensity Score Models

In addition to purposeful selection model building, propensity score models were used to assess the relationship between the outcomes and exposures. Propensity score models are often used in observational studies where the exposure variable cannot be randomly assigned. A propensity score represents the conditional probability of being exposed, or treated, given a set of covariates (162). It aims to control for factors that may ultimately influence exposure. In this study, exposure is not random and there are many factors that may contribute to whether or not a participant is exposed to the variables of interest. In the propensity score model, the exposure variable is dichotomized as absent vs. present or low exposure vs. high exposure. The exposure variable is fit into a logistic regression model as the outcome in order to model the probability distribution of the exposure (either the presence or high exposure of the variable as the event) given the covariates of interest. This technique produces a continuous variable, known as the propensity score, which is used to reduce bias by balancing to covariates between the exposed and unexposed groups (162). Specifically, the propensity score is the model estimated log odds ratio conditional on the covariates of interest. Finally, the exposure and the corresponding propensity score are included in a logistic regression model as predictors with the outcome of interest as the response.

Analyses for Aims 1 and 2

Data analyses of Aims 1 and 2 include a total of 79 participants, all whom completed the air filter portion of the study. Three of the participants, 003, 012, 067, are missing data from the PHH, 032 is missing data from selected questions of the PHH, 040 is missing data from the HCQ, and 031 is missing data from selected questions of the EHHQ.

Specific Aim 1: *Evaluate the roles of PM_{10} and fly ash in the home environment on anxiety and/or depression problems in children, as indicated by the Child Behavior Checklist.*

Subaim 1A. Determine if children with elevated PM_{10} concentrations or fly ash in their home environment have higher odds of anxiety problems than children with low PM_{10} concentrations and no fly ash.

Subaim 1B. Determine if children with elevated PM_{10} concentrations or fly ash in their home environment have higher odds of depression problems than children with low PM_{10} concentrations and no fly ash.

Subaim 1C. Determine if children with elevated PM_{10} concentrations or fly ash in their home environment have higher odds of anxiety and/or depression problems than children with low PM_{10} concentrations and no fly ash.

PM_{10} and Fly Ash Exposure

The exposure variables used throughout Aim 1 were PM_{10} concentrations as determined from gravimetric analysis of the air filters and fly ash presence/absence as determined by SEM. PM_{10} was dichotomized into low or high concentrations, using the median due to the non-normal distribution of the continuous variable. Fly ash on the filter was naturally dichotomized into absence or presence of fly ash.

Specific Aim 2: *Determine the effects of elevated metal concentrations in the home environment on anxiety and/or depression problems in children.*

Subaim 2A. Determine if children with elevated metal concentrations in their home environment have higher odds of anxiety problems than children with lower metal concentrations.

Subaim 2B. Determine if children with elevated metal concentrations in their home environment have higher odds of depression problems than children with lower metal concentrations.

Subaim 2C. Determine if children with elevated metal concentrations in their home environment have higher odds of anxiety and/or depression problems than children with lower metal concentrations.

Filter Metals

The filter metal concentrations were dichotomized for analyses. Metal concentrations that were below the limit of detection (LOD) were coded as 0 ppm. In some cases, it is reasonable to code concentrations below the LOD as the lower LOD, however it not optimal in this case because the LOD differed for each PIXE analysis. Therefore, one participant could arbitrarily be assigned a higher ppm than another participant, regardless of the actual unknown concentration on the filter. This would also cause issues when ranking the metal concentrations for the total metal score, which will be discussed in a subsequent section. Furthermore, using the concentration as zero for elements below the LOD produces a more conservative estimate of the values.

Metals were dichotomized either as absent/present or low/high concentrations based on the available data. For example, metals were dichotomized as absent or present when 50% or more of the concentration values were below the LOD. The metals included in this method are arsenic, chromium, manganese, and nickel. Alternatively, metals that had more than 50% of detected concentration values were dichotomized into low or high concentration levels. Metals dichotomized into low or high levels included aluminum, copper, iron, titanium, and zinc. The median for each metal was used as the cut off value, as all were non-normally distributed.

Filter Metal Score

A total filter metal score was calculated to assess a cumulative exposure measure for the nine metals being investigated in the filter analyses: aluminum, arsenic, chromium, copper, iron, nickel, manganese, titanium, and zinc. Each metal was ranked in ascending order, where the lowest rank value corresponded with the lowest metal concentration and the highest rank value corresponded with the highest metal concentration. Metal concentrations that were below the LOD were coded as 0 ppm and ranked accordingly.

To address a tie in rank, the minimum corresponding rank was assigned to each participant. The ranks for each metal were then summed to calculate a total metal score. This metal ranking technique has been published in other literature (163). For analytical purposes, the total metal score was dichotomized. The total filter metal score was not normally distributed, therefore for dichotomization, the median was used as the cut point; 0 is defined as a total metal score less than or equal to 268, 1 is defined as a total metal score greater than 268.

Purposeful Selection Models – Aims 1 and 2

Purposeful selection models were created for each of the exposures in Aims 1 and 2, separately. Aim 1 exposures include PM_{10} and fly ash. Aim 2 exposures include filter aluminum, arsenic, chromium, copper, iron, manganese, nickel, titanium, and zinc. For each outcome (anxiety, withdrawn/depressed, anxious/depressed problems), there are 11 final models, one for each investigated exposure. Simple logistic regression analyses of each outcome (anxiety, withdrawn/depressed, and anxious depressed problems) identified covariates of interest. The covariates of interest were included in the 11 initial purposeful selection multiple logistic regression models for the respective outcome. Additionally, variables that were significantly different between exposure status in the demographic tables and cleaning tables were considered in the multiple logistic regression models for the corresponding exposure. A final, adjusted model including covariates determined from the purposeful selection model building technique, described in a previous section, is reported for each of the 11 exposure variables assessed in Aims 1 and 2 by outcome. There are 33 final purposeful selection models reported for Aims 1 and 2.

Propensity Score Models – Aims 1 and 2

For Aim 1, propensity scores were created for PM_{10} and fly ash. For Aim 2, a propensity score for the total filter metal score, described in a previous section, was used in a final logistic regression model with each metal of interest. Each propensity was estimated conditional on age, gender, race, SES category, parents' marriage status, mother's depression status, frequency of smoking in the home, and frequency the entire home was cleaned each week.

Analyses for Aim 3

Data analyses for Aim 3 includes a total of 69 participants, all which completed the nail collection portion of the study. One participant, 032, is missing data from selected questions of the PHH and 031 is missing data from selected questions of the EHHQ.

Specific Aim 3: *Determine the effects of elevated metal concentrations in the body on anxiety and/or depression problems in children.*

Subaim 3A. Determine if children with elevated metal body burdens have higher odds of anxiety problems than children with lower metal body burdens.

Subaim 3B. Determine if children with elevated metal body burdens have higher odds of depression problems than children with lower metal body burdens.

Subaim 3C. Determine if children with elevated metal body burdens have higher odds of anxiety and/or depression problems than children with lower metal body burdens.

Nail Metals

Metals were dichotomized either as absent/present or low/high concentrations based on the available data. For example, metals were dichotomized as absent or present when 50% or more of the concentration values were below the LOD. This included arsenic, manganese, and titanium. Metals that had 50% or more detected concentrations were dichotomized into low or high concentration levels. The median was used for metals that were not normally distributed, including aluminum, chromium, copper, iron, nickel, and zinc.

Nail Metal Score

The total nail metal score was calculated as described in the filter metal score section. It was calculated to assess a cumulative exposure measure for the nine metals being investigated in the nail analyses: aluminum, arsenic, chromium, copper, iron, nickel, manganese, titanium, and zinc. The total nail metal score was not normally distributed, therefore for dichotomization the median was used as a cut point; 0 is defined as a total metal score less than or equal to 223, 1 is defined as a total metal score greater than 223.

Purposeful Selection Models – Aim 3

Purposeful selection models were created for each of the exposures in Aim 3. Aim 3 exposures include nail aluminum, arsenic, chromium, copper, iron, manganese, nickel, titanium, and zinc. For each outcome (anxiety, withdrawn/depressed, anxious/depressed problems) there are 9 final models, one for each investigated exposure. Simple logistic regression analyses of each outcome identified variables of interest that were included in the 9 initial purposeful selection multiple logistic regression models for the respective outcome. Additionally, variables that were significantly different between exposure status in the demographic tables and cleaning tables were considered in the purposeful selection multiple logistic regression models of the corresponding exposure. A final, adjusted model for each metal exposure by outcome is reported. In total, 27 final models are reported for Aim 3.

Propensity Score Models – Aim 3

Similarly to Aim 2, a propensity score for the total nail metal score, described in a previous section, was used in a final logistic regression model with each metal of interest. Each propensity score model was estimated conditional on age, gender, race, SES category, parents' marriage status, mother's depression status, frequency of smoking in the home, and frequency the entire home was cleaned each week.

RESULTS

Results for Aims 1 and 2

Demographics – Aims 1 and 2

As previously described, demographic characteristics and cleaning behaviors were assessed by outcome and by exposure. Table 1 displays selected demographic and environmental characteristics by the outcome assessed in Subaim A for Aims 1 and 2, anxiety problems. Demographic tables for the outcome in Subaim B, withdrawn/depressed problems, and the outcome in Subaim C, anxious/depressed problems, can be found in the appendix (Tables 21 - 22).

There were 66 children that scored in the normal t-score range for anxiety problems and 13 children that scored in the borderline or clinically significant range for anxiety problems. None of the variables assessed in Table 1, using Chi-squared or Fisher's Exact p-values where appropriate, were significantly different between the two groups suggesting that those children with and without anxiety problems are comparable. Two of the variables, age and mom's depression, approached significance with p-values $\approx$0.06.

Table 1. Demographics by Anxiety Problems for Aims 1 and 2

	Anxiety Problems (N=79)				
	t-score <65		t-score ≥ 65		
	Count (N=66)	Percent[A]	Count (N=13)	Percent[A]	p-value
Gender					0.45
Male	33	50%	8	62%	
Female	33	50%	5	38%	
Age					0.06[B]
6-8 years	17	26%	2	15%	
9-11 years	18	27%	4	31%	
12-14 years	31	47%	7	54%	
Race					0.58[B]
White	48	73%	12	92%	
African American	15	23%	1	8%	
AI/AN	2	3%	0	0%	
Asian	1	2%	0	0%	
SES					0.69[B]
Low	24	36%	5	38%	
Middle	19	29%	5	38%	
High	23	35%	3	23%	
Parents' Marriage Status					0.27
Married	46	70%	7	54%	
Unmarried	20	30%	6	46%	
Smoking in the Home					0.69[B]
No	54	82%	10	77%	
Yes	11	17%	3	23%	
Freq of Smoking in Home					1.00[B]
None	56	85%	12	92%	
Rarely-Frequently	9	14%	1	8%	
Mom Anxiety					0.72[B]
No	46	70%	7	54%	
Yes	18	27%	4	31%	
Mom Depression					0.06
No	47	71%	5	38%	
Yes	17	26%	6	46%	

A. Numbers may not add to 100% due to rounding or missing data.

B. Fisher's Exact p-value.

Based on the tables in the appendix, of the 79 participants, 12 scored in the borderline or clinically significant range for withdrawn/depressed problems. There were no significant differences found between those children without withdrawn/depressed problems and those children with withdrawn/depressed problems (Table 21 in Appendix). Finally, children with anxious/depressed problems were more likely to have mother's that reported depression than children without anxious/depressed problems. Of the 64 children with normal t-scores, only 16 had mothers that were depressed (25%), and of the 15 children with borderline or clinically significant t-scores for anxious/depressed problems, 7 had mothers that were depressed (47%), p-value=0.05, (Table 22 in Appendix).

In this population, 20 children had at least one outcome. Seven of those children had all three outcomes. A cross table (2x2x2) of outcomes can be found in the appendix (Table 23).

Cleaning Behaviors – Aims 1 and 2

In addition to demographic variables, several cleaning behaviors were assessed by outcome and investigated as potential covariates or confounders. Table 2 displays the selected cleaning behaviors by <u>anxiety problems</u>. There were no significant differences found between those children without anxiety problems and those children with anxiety problems.

Table 2. Cleaning Behaviors by Anxiety Problems for Aims 1 and 2

	Anxiety Problems				
	t-score <65		t-score ≥ 65		
	Count (N=66)	Percent[A]	Count (N=13)	Percent[A]	p-value
How frequently do you keep the windows open?					0.23
Never or Rarely	19	29%	6	46%	
Sometimes, Frequently, or As Much As Possible	46	70%	7	54%	
How frequently do you clean your entire home?					0.48[B]
1 or Fewer Times per Week	51	77%	9	69%	
2-7 Times per Week	14	21%	4	31%	
How frequently are wet methods used to clean your home?					0.55[B]
1 or Fewer Times per Week	38	58%	9	69%	
2-7 Times per Week	27	41%	4	31%	
How frequently are dry methods used to clean your home?					0.54[B]
1 or Fewer Times per Week	37	56%	9	69%	
2-7 Times per Week	28	42%	4	31%	

A. Numbers may not add to 100% due to rounding or missing data.
B. Fisher's Exact p-value.

Similar tables were created for withdrawn/depressed and anxious/depressed problems, which can be found in the appendix (Tables 24-25). The frequency the windows were kept opened in the home (never or rarely vs. sometimes, frequency, or as much as possible) significantly differed by children without withdrawn/depressed problems and children with withdrawn/depressed problems (p-value=0.03). Children with withdrawn/depressed problems were more likely to never or rarely have the windows open in the home when compared to children without withdrawn/depressed problems (58% vs. 27%, respectively). There were no significant differences found between children without anxious/depressed problems or children with anxious/depressed problems.

Demographics by PM_{10} Level – Aim 1

Table 3 displays selected demographic and environmental characteristics for low (<16.53 $\mu g/m^3$) vs. high concentration (≥16.53 $\mu g/m^3$) of PM_{10}. The distribution of low, middle, and high SES families is significantly different among low and high PM_{10} concentration levels (p-value=0.05); a larger proportion of low PM_{10} concentration levels were comprised of high SES families when compared to high PM_{10} concentration levels (46% vs. 20%, respectively). Parents' marriage status (married vs. unmarried) was significantly different between low and high PM_{10} concentration levels (p-value<0.01). Parents' marriage status was evenly distributed within high PM_{10} concentrations, whereas 85% of participants with low PM_{10} concentrations had married parents. These variables, SES and parents' marriage status, were considered in subsequent analysis.

Table 3. Demographics by PM_{10} Exposure for Aim 1

	PM_{10} Levels (N=79)				
	Low <16.53 $\mu g/m^3$		High ≥16.53 $\mu g/m^3$		
	Count (N=39)	Percent[A]	Count (N=40)	Percent[A]	p-value
Gender					0.43
Male	22	56%	19	48%	
Female	17	44%	21	53%	
Age					0.59
6-8 years	8	21%	11	28%	
9-11 years	10	26%	12	30%	
12-14 years	21	54%	17	43%	

Race					0.34[B]
White	32	82%	28	70%	
African American	7	18%	9	23%	
AI/AN	0	0%	2	5%	
Asian	0	0%	1	3%	
SES					0.05
Low	12	31%	17	43%	
Middle	9	23%	15	38%	
High	18	46%	8	20%	
Parents' Marriage Status					<0.01
Married	33	85%	20	50%	
Unmarried	6	15%	20	50%	
Smoking in the Home					0.14[B]
No	35	90%	29	73%	
Yes	4	10%	10	25%	
Freq of Smoking in Home					0.09[B]
None	37	95%	31	78%	
Rarely-Frequently	2	5%	8	20%	

A. Numbers may not add to 100% due to rounding or missing data.
B. Fisher's Exact p-value.

Tables displaying selected demographics and environmental characteristics by fly ash and home environmental metal exposures can be found in the appendix (Tables 26 - 35). Tables describing cleaning behaviors by PM_{10}, fly ash, and home environmental metal exposures can also be found in the appendix (Tables 36 - 46).

Final Logistic Regression Models – Aims 1 and 2

Unadjusted Models – Aims 1 and 2

Table 4 shows the unadjusted logistic regression models of anxiety problems for Aims 1 and 2.

Table 4. Unadjusted Modeling of Anxiety Problems for Aims 1 and 2

Models	Exposure vs Reference	OR	95% CI	p-value
PM_{10}	High vs Low	1.17	0.35 - 3.84	0.80
Fly Ash	Present vs Absent	1.09	0.32 - 3.72	0.89
Arsenic	Present vs Absent	0.71	0.21 - 2.38	0.58
Chromium	Present vs Absent	0.38	0.04 - 3.17	0.37
Manganese	Present vs Absent	1.16	0.35 - 3.84	0.80
Nickel	Present vs Absent	1.24	0.38 - 4.09	0.72
Aluminum	High vs Low	1.81	0.54 - 6.10	0.34
Copper	High vs Low	2.70	0.76 - 9.65	0.13
Iron	High vs Low	1.81	0.54 - 6.10	0.34
Titanium	High vs Low	1.24	0.38 - 4.09	0.72
Zinc	High vs Low	1.92	0.57 - 6.49	0.29

Similar tables of unadjusted logistic regression models of investigated exposures by withdrawn/depressed and anxious/depressed problems for Aims 1 and 2 can be found in the appendix (Tables 47 - 48). Nickel (present vs. absent) approached statistical significance (OR=0.29, 95% CI: 0.07–1.56, p-value=0.08), for withdrawn/depressed problems. Copper (high vs. low levels) was statistically significant in the unadjusted model of anxious/depressed problems (OR=3.54, 95% CI: 1.02-12.30, p-value=0.05). This suggests that children exposed to high copper levels have 3.54 times the odds of having anxious/depressed problems when compared to children exposed to low copper levels.

Simple Regression Analyses for Purposeful Selection Models – Aims 1 and 2

As previously described, the first step in purposeful selection model building is to run simple logistic regression models for potential covariates or confounders by outcome. Table 5 displays the variables that were found to be liberally significant (p-value <0.20) through simple logistic regression analyses for each outcome assessed in Aims 1 and 2, anxiety problems, withdrawn/depressed problems, and anxious/depressed problems. A complete list of simple logistic regression analyses by outcome can be found in Tables 49 – 51 in the appendix.

Table 5. Variables Identified by Simple Regression Analyses for Aims 1 and 2

Variable	OR	95% CI	p-value
Anxiety Problems			
Mom Depression (Yes vs No)	3.32	0.90 - 12.30	0.07
Withdrawn/Depressed Problems			
Age	1.21	0.92 - 1.60	0.17
Mom Depression (Yes vs No)	3.32	0.90 - 12.30	0.07
Windows Open (Sometimes or More vs Never or Rarely)	0.27	0.08 - 0.95	0.04
Anxious/Depressed Problems			
Mom Depression (Yes vs No)	3.35	0.98 - 11.47	0.05
Windows Open (Sometimes or More vs Never or Rarely)	0.46	0.14 - 1.45	0.18

Mom's depression status in the anxiety problems model was liberally significant (p-value=0.07) and therefore included in subsequent purposeful selection multiple logistic regression models of <u>anxiety problems</u> for Aims 1 and 2. Age (p-value=0.17), mom's depression status (p-value=0.07), and frequency the windows were kept open in the home (p-value=0.04) were all variables included in the purposeful selection multiple logistic regression models of <u>withdrawn/depressed problems</u> for Aims 1 and 2. Finally, mom's depression status (p-value=0.05) and frequency the windows were kept open in the home (p-value=0.18) were identified through simple logistic regression analyses of <u>anxious/depressed problems</u> and included in the subsequent purposeful selection multiple logistic regression models of anxious/depressed problems for Aims 1 and 2. Additionally, covariates that were significantly different by exposure status were considered in the purposeful selection multiple logistic regression models of the respective exposure. These are as follows: PM_{10}: SES category, parents' marriage status, and frequency of cleaning the entire home; aluminum: SES category, parents' marriage status, frequency the windows were kept open in the home, and frequency the entire home was cleaned; copper: race; iron: SES category, parents' marriage status, and frequency the entire home was cleaned; titanium: SES category; and zinc: parents' marriage status.

Purposeful Selection Models of Anxiety – Aims 1 and 2

Table 6 displays the final purposeful selection adjusted logistic regression models of <u>anxiety problems</u> for each of the exposure variables explored in Aims 1 and 2. None of the exposure variables were statistically significant. It is important to note that including mom's depression status improved the fit of every model, though it was only statistically significant in the PM_{10} model (p-value=0.05). The AOR=4.22, meaning that the odds of having <u>anxiety problems</u> were 4.22 times greater for children with depressed mothers than for children without depressed mothers.

Table 6. Adjusted Modeling of Anxiety Problems for Aims 1 and 2

Variables	AOR	95% CI	p-value
PM_{10} Model			
PM_{10} (High vs Low)	0.60	0.14 - 2.52	0.48
Mom Depression (Yes vs No)	4.22	1.04 - 17.19	0.05
Freq of Cleaning Home (2 or more vs 1 or fewer times per week)	0.80	0.14 - 4.62	0.80
Fly Ash Model			
Fly Ash (Present vs Absent)	1.32	0.35 - 5.06	0.68
Mom Depression (Yes vs No)	3.17	0.84 - 11.96	0.09
Arsenic Model			
Arsenic (Present vs Absent)	0.46	0.11 - 1.97	0.30

Mom Depression (Yes vs No)	3.26	0.87 - 12.24	0.08
Chromium Model			
Chromium (Present vs Absent)	<0.01	<0.01 - >999.99	0.97
Mom Depression (Yes vs No)	3.34	0.88 - 12.70	0.08
Manganese Model			
Manganese (Present vs Absent)	0.98	0.26 - 3.69	0.97
Mom Depression (Yes vs No)	3.33	0.89 - 12.50	0.08
Nickel Model			
Nickel (Present vs Absent)	1.43	0.38 - 5.39	0.60
Mom Depression (Yes vs No)	3.44	0.92 - 12.89	0.07
Aluminum Model			
Aluminum (High vs Low)	1.41	0.30 - 6.65	0.66
Mom Depression (Yes vs No)	3.38	0.84 - 13.57	0.09
SES (0 vs 2)	0.82	0.13 - 5.07	0.83
SES (1 vs 2)	1.04	0.15 - 7.31	0.97
Windows Open (Sometimes or More vs Never or Rarely)	0.651	0.13 - 3.31	0.61
Freq of Cleaning Home (2 or more vs 1 or fewer times per week)	0.70	0.10 - 4.85	0.71
Copper Model			
Copper (High vs Low)	1.66	0.64 - 11.38	0.51
Mom Depression (Yes vs No)	3.25	0.79 - 11.33	0.09
Race (White vs Non-White)	>999.99	<0.01 - >999.99	0.96
Iron Model			
Iron (High vs Low)	1.44	0.37 - 5.65	0.61
Mom Depression (Yes vs No)	3.76	0.99 - 14.24	0.05
Freq of Cleaning Home (2 or more vs 1 or fewer times per week)	0.72	0.12 - 4.22	0.72
Titanium Model			
Titanium (High vs Low)	0.87	0.22 - 3.42	0.84
Mom Depression (Yes vs No)	3.45	0.88 - 13.56	0.08
Zinc Model			
Zinc (High vs Low)	1.34	0.36 - 5.01	0.66
Mom Depression (Yes vs No)	3.25	0.87 - 12.10	0.08

Propensity Score Models of Anxiety – Aims 1 and 2

Table 7 shows the results of the logistic regression adjusted propensity score models of anxiety problems for Aims 1 and 2. A separate propensity score was created for PM_{10}, fly ash, and total filter metal score. The propensity calculated from the total filter metal score was used in the logistic regression adjusted models for each of the investigated metals. Covariates in each propensity score model include: age, gender, race, SES category, parents' marriage status, mom's depression status, frequency of smoking in the home, and frequency of cleaning the entire home each week.

Table 7. Anxiety Problems Propensity Score Modeling for Aims 1 and 2

Model	AOR	95% CI	p-value
PM_{10} (High vs Low)	0.92	0.21 - 4.04	0.91
Fly Ash (Yes vs No)	1.33	0.34 - 5.19	0.68
Filter Metal Score	0.44	0.10 - 1.83	0.26
Arsenic (Present vs Absent)	0.37	0.09 - 1.59	0.18
Chromium (Present vs Absent)	<0.01	<0.01 - >999.99	0.96
Manganese (Present vs Absent)	1.07	0.28 - 4.06	0.92
Nickel (Present vs Absent)	1.34	0.37- 4.87	0.66
Aluminum (High vs Low)	1.21	0.30 - 4.88	0.79
Copper (High vs Low)	2.99	0.69 - 12.90	0.14
Iron (High vs Low)	1.23	0.31 - 4.87	0.77
Titanium (High vs Low)	1.08	0.28 - 4.17	0.91
Zinc (High vs Low)	1.42	0.38 - 5.32	0.61

Tables displaying the parameter estimates, standard errors, ORs, 95% confidence intervals, and p-values for each covariate by outcome for Aims 1 and 2 can be found in the appendix (Tables 52 - 54). Similar to the purposeful selection adjusted models of anxiety problems, no significant propensity score models of anxiety problems are reported.

Purposeful Selection Models of Withdrawn/Depressed – Aims 1 and 2

Table 8 displays the final purposeful selection adjusted logistic regression models of withdrawn/depressed problems from Aims 1 and 2. None of the exposure variables reached statistical significance in these models. Mom's depression status was significant in several models: PM_{10}, fly ash, arsenic, manganese, aluminum, iron, and titanium. In these models, the odds of having withdrawn/depressed problems were significantly greater for children with depressed mothers when compared to children without depressed mothers. Additionally, frequency the windows were kept open in the home (sometimes or more vs. never or rarely) was significant in several models: PM_{10}, chromium, nickel, iron, and titanium. In these models, the odds of having withdrawn/depressed problems were significantly greater for children who had the windows rarely or never open when compared to children who had windows open sometimes or more.

Table 8. Adjusted Modeling of Withdrawn/Depressed Problems for Aims 1 and 2

Variables	AOR	95% CI	p-value
PM_{10} Model			
PM_{10} (High vs Low)	0.21	0.02 - 1.74	0.15
Mom Depression (Yes vs No)	13.57	1.73 - 106.19	0.01
Age	1.28	0.90 - 1.81	0.17
Windows Open (Sometimes or More vs Never or Rarely)	0.18	0.03 - 0.94	0.04
SES (0 vs 2)	1.17	0.18 - 7.49	0.87
SES (1 vs 2)	0.18	0.02 - 2.10	0.17
Fly Ash Model			
Fly Ash (Present vs Absent)	0.68	0.14 - 3.31	0.63
Mom Depression (Yes vs No)	4.54	1.00 - 20.53	0.05
Age	1.25	0.92 - 1.70	0.16
Windows Open (Sometimes or	0.24	0.05 - 1.03	0.06

More vs Never or Rarely)			
Arsenic Model			
Arsenic (Present vs Absent)	1.68	0.39 - 7.17	0.48
Mom Depression (Yes vs No)	4.38	1.02 - 18.77	0.05
Age	1.24	0.92 - 1.66	0.16
Windows Open (Sometimes or More vs Never or Rarely)	0.24	0.06 - 1.02	0.05
Chromium Model			
Chromium (Present vs Absent)	<0.01	<0.01 - >999.99	0.97
Mom Depression (Yes vs No)	4.19	0.98 - 17.82	0.06
Windows Open (Sometimes or More vs Never or Rarely)	0.22	0.05 - 0.93	0.04
Manganese Model			
Manganese (Present vs Absent)	0.24	0.04 - 1.32	0.10
Mom Depression (Yes vs No)	4.56	1.05 - 19.88	0.04
Age	1.24	0.92 - 1.69	0.16
Windows Open (Sometimes or More vs Never or Rarely)	0.30	0.07 - 1.29	0.11
Nickel Model			
Nickel (Present vs Absent)	0.34	0.08 - 1.51	0.16
Mom Depression (Yes vs No)	3.63	0.88 - 14.92	0.07
Windows Open (Sometimes or More vs Never or Rarely)	0.23	0.06 - 0.96	0.04
Aluminum Model			
Aluminum (High vs Low)	0.60	0.13 - 2.79	0.51
Mom Depression (Yes vs No)	4.72	1.07 - 20.89	0.04
Age	1.21	0.90 - 1.63	0.20
Windows Open (Sometimes or More vs Never or Rarely)	0.30	0.07 - 1.30	0.11
Copper Model			
Copper (High vs Low)	1.01	0.23 - 4.46	0.99
Mom Depression (Yes vs No)	4.01	0.92 - 17.60	0.07
Age	1.23	0.88 - 1.72	0.22
Windows Open (Sometimes or More vs Never or Rarely)	0.35	0.08 - 1.49	0.16
Race (White vs Non-White)	>999.99	<0.01 - >999.99	0.96
Iron Model			

Iron (High vs Low)	1.12	0.25 - 5.02	0.89
Mom Depression (Yes vs No)	6.75	1.31 - 34.67	0.02
Age	1.19	0.88 - 1.63	0.26
SES (0 vs 2)	0.63	0.12 - 3.41	0.59
SES (1 vs 2)	0.15	0.01 - 1.63	0.12
Windows Open (Sometimes or More vs Never or Rarely)	0.16	0.03 - 0.83	0.03
Titanium Model			
Titanium (High vs Low)	0.27	0.05 - 1.48	0.13
Mom Depression (Yes vs No)	8.31	1.54 - 45.02	0.01
SES (0 vs 2)	0.68	0.13 - 3.66	0.66
SES (1 vs 2)	0.25	0.03 - 2.61	0.25
Windows Open (Sometimes or More vs Never or Rarely)	0.20	0.04 - 0.99	0.05
Zinc Model			
Zinc (High vs Low)	1.13	0.28 - 4.60	0.87
Mom Depression (Yes vs No)	4.04	0.98 - 16.71	0.05
Age	1.23	0.91 - 1.65	0.17
Windows Open (Sometimes or More vs Never or Rarely)	0.26	0.06 - 1.07	0.06

Propensity Score Models of Withdrawn/Depressed – Aims 1 and 2

Table 9 shows the results of the logistic regression adjusted propensity score models of withdrawn/depressed problems for Aims 1 and 2. The filter metal score model was significant (p-value=0.03). For odds ratios below 1, inversing the odds and interpreting the results for the children with low total metal scores is more straightforward. In this case, children with low filter metal scores had 6.94 times the odds (1 / 0.14) of being withdrawn/depressed than children with high filter metal scores. This finding is somewhat perplexing and will be addressed further in the discussion.

Table 9. Withdrawn/Depressed Propensity Score Modeling for Aims 1 and 2

Model	AOR	95% CI	p-value
PM_{10} (High vs Low)	0.46	0.09 - 2.26	0.34
Fly Ash (Yes vs No)	1.12	0.28 - 4.47	0.88
Filter Metal Score (High vs Low)	0.14	0.03 - 0.80	0.03
Arsenic (Present vs Absent)	1.03	0.28 - 3.83	0.96
Chromium (Present vs Absent)	<0.01	<0.01 - >999.99	0.96
Manganese (Present vs Absent)	0.23	0.04 - 1.20	0.08
Nickel (Present vs Absent)	0.35	0.08 - 1.43	0.14
Aluminum (High vs Low)	0.50	0.12 - 2.10	0.34
Copper (High vs Low)	1.95	0.49 - 7.75	0.34
Iron (High vs Low)	0.85	0.21 - 3.36	0.81
Titanium (High vs Low)	0.27	0.06 - 1.18	0.08
Zinc (High vs Low)	0.96	0.26 - 3.59	0.95

Purposeful Selection Models of Anxious/Depressed – Aims 1 and 2

Table 10 shows the final purposeful selection adjusted logistic regression models of anxious/depressed problems for Aims 1 and 2. None of the exposure variables were considered to be statistically significant in these models. Mom's depression status was significant in several models: PM_{10}, fly ash, manganese, nickel, aluminum, iron, titanium, and zinc. In these models, the odds of having anxious/depressed problems were significantly greater for children with depressed mothers when compared to children without depressed mothers.

Table 10. Adjusted Modeling of Anxious/Depressed Problems for Aims 1 and 2

Variables	AOR	95% CI	p-value
PM_{10} Model			
PM_{10} (High vs Low)	1.52	0.38 - 6.03	0.55
Mom Depression (Yes vs No)	5.91	1.34 - 25.99	0.02
Freq of Cleaning Home (2 or more vs 1 or fewer times per week)	0.25	0.03 - 2.27	0.22

Married (No vs Yes)	0.31	0.05 - 1.78	0.19
Fly Ash Model			
Fly Ash (Present vs Absent)	0.77	0.20 - 2.98	0.70
Mom Depression (Yes vs No)	3.65	1.01 - 13.21	0.05
Windows Open (Sometimes or More vs Never or Rarely)	0.52	0.13 – 2.00	0.34
Arsenic Model			
Arsenic (Present vs Absent)	0.56	0.15 - 2.06	0.38
Mom Depression (Yes vs No)	3.31	0.96 - 11.40	0.06
Chromium Model			
Chromium (Present vs Absent)	0.44	0.05 - 3.93	0.46
Mom Depression (Yes vs No)	3.34	0.97 - 11.48	0.06
Manganese Model			
Manganese (Present vs Absent)	0.48	0.12 - 1.90	0.30
Mom Depression (Yes vs No)	3.82	1.06 - 13.69	0.04
Windows Open (Sometimes or More vs Never or Rarely)	0.64	0.17 - 2.44	0.51
Nickel Model			
Nickel (Present vs Absent)	2.11	0.59 - 7.55	0.25
Mom Depression (Yes vs No)	3.67	1.04 - 12.91	0.04
Aluminum Model			
Aluminum (High vs Low)	0.90	0.24 - 3.42	0.88
Mom Depression (Yes vs No)	4.21	1.13 - 15.73	0.03
Freq of Cleaning Home (2 or more vs 1 or fewer times per week)	0.22	0.02 - 1.98	0.18
Copper Model			
Copper (High vs Low)	2.29	0.53 - 9.82	0.27
Mom Depression (Yes vs No)	3.25	0.88 - 12.02	0.08
Race (White vs Non-White)	>999.99	<0.01 - >999.99	0.96
Iron Model			
Iron (High vs Low)	2.76	0.65 - 11.71	0.17
Mom Depression (Yes vs No)	9.94	1.70 - 58.34	0.01
SES (0 vs 2)	1.00	0.21 - 4.87	1.00
SES (1 vs 2)	0.35	0.04 - 2.942	0.33
Married (No vs Yes)	0.18	0.03 - 1.35	0.10

Windows Open (Sometimes or More vs Never or Rarely)	0.53	0.12 - 2.30	0.39
Freq of Cleaning Home (2 or more vs 1 or fewer times per week)	0.32	0.03 - 3.61	0.36
Titanium Model			
Titanium (High vs Low)	0.71	0.18 - 2.84	0.63
Mom Depression (Yes vs No)	4.33	1.10 - 16.99	0.04
SES (0 vs 2)	0.98	0.22 - 4.45	0.98
SES (1 vs 2)	0.50	0.08 - 3.28	0.47
Windows Open (Sometimes or More vs Never or Rarely)	0.52	0.13 - 2.07	0.35
Zinc Model			
Zinc (High vs Low)	1.97	0.52 - 7.49	0.32
Mom Depression (Yes vs No)	6.56	1.47 - 29.28	0.01
Married (No vs Yes)	0.22	0.04 - 1.26	0.09
Windows Open (Sometimes or More vs Never or Rarely)	0.54	0.14 - 2.06	0.36

Propensity Score Models of Anxious/Depressed – Aims 1 and 2

Table 11 shows the results of the logistic regression adjusted propensity score models of anxious/depressed problems for Aims 1 and 2. Copper exposure in the copper propensity score model was significant (p-value=0.05). The AOR=4.24, meaning that the odds of being anxious/depressed are 4.24 times greater for those exposed to high copper levels than those exposed to low copper levels.

Table 11. Anxious/Depressed Propensity Score Modeling for Aims 1 and 2

Model	AOR	95% CI	p-value
PM_{10} (High vs Low)	2.29	0.60 - 8.83	0.23
Fly Ash (Yes vs No)	0.83	0.22 - 3.12	0.79
Filter Metal Score	0.50	0.13 - 1.90	0.31
Arsenic (Present vs Absent)	0.45	0.12 - 1.69	0.24
Chromium (Present vs Absent)	0.46	0.05 – 4.05	0.49
Manganese (Present vs Absent)	0.49	0.13 - 1.85	0.29
Nickel (Present vs Absent)	1.93	0.56 - 6.60	0.30
Aluminum (High vs Low)	0.79	0.22 - 2.93	0.73
Copper (High vs Low)	4.24	1.01 - 17.81	0.05
Iron (High vs Low)	1.24	0.34 - 4.50	0.74
Titanium (High vs Low)	0.72	0.20 - 2.54	0.61
Zinc (High vs Low)	1.42	0.41 - 4.86	0.58

Results for Aim 3

Demographics and Cleaning Behaviors – Aim 3

Table 12 displays selected demographic and environmental characteristics by the outcome assessed in Subaim A for Aim 3, anxiety problems. There were 59 children that scored in the normal t-score range for anxiety problems and 10 children that scored in the borderline or clinically significant range for anxiety problems. Using Chi-squared or Fisher's Exact p-values where appropriate, children with anxiety problems were significantly more likely to have a mother with depression than children without anxiety problems (50% vs. 20%, respectively, p-value=0.05).

Table 12. Demographics by Anxiety Problems for Aim 3

	Anxiety Problems (N=69)				
	t-score <65		t-score ≥ 65		
	Count (N=59)	Percent[A]	Count (N=10)	Percent[A]	p-value
Gender					0.19[B]
Male	27	46%	7	70%	
Female	32	54%	3	30%	
Age					0.61[B]
6-8 years	16	27%	1	10%	
9-11 years	16	27%	3	30%	
12-14 years	27	46%	6	60%	
Race					0.24[B]
White	44	75%	10	100%	
African American	14	24%	0	0%	
Asian	1	2%	0	0%	
SES					1.00[B]
Low	20	34%	4	40%	
Middle	18	31%	3	30%	
High	21	36%	3	30%	
Parents' Marriage Status					0.45[B]
Married	44	75%	6	60%	
Unmarried	15	25%	4	40%	
Smoking in the Home					1.00[B]
No	48	81%	8	80%	
Yes	10	17%	2	20%	
Freq of Smoking in Home					1.00[B]
None	49	83%	9	90%	
Rarely-Frequently	9	15%	1	10%	
Mom Anxiety					0.47[B]
No	42	71%	6	60%	
Yes	16	27%	4	40%	
Mom Depression					0.05
No	46	78%	5	50%	
Yes	12	20%	5	50%	

A. Numbers may not add to 100% due to rounding or missing data.
B. Fisher's Exact p-value.

Demographic tables for the outcome in Subaim B, withdrawn/depressed problems, and the outcome in Subaim C, anxious/depressed problems, can be found in the appendix (Tables 55 - 56). Of the 69 participants, 9 scored in the borderline or clinically significant range for withdrawn/depressed problems and 10 scored in the borderline or clinically significant range for anxious/depressed problems. There were no significant differences found between withdrawn/depressed outcomes, suggesting that the population is comparable. Mom's depression status was found to be significantly different between children without anxious/depressed problems and children with anxious/depressed problems (p-value=0.05). Similarly to anxiety problems, 50% of children with anxious/depressed problems had mothers with depression when compared to only 12% of children without anxious/depressed problems.

Demographic tables by metal body burden exposures can be found in the appendix (Tables 57 - 65). In this population, 14 children had at least one outcome. Five of those children had all three outcomes. A cross table (2x2x2) of outcomes can be found in the appendix (Table 66).

Cleaning behaviors were also assessed for each outcome and exposure in Aim 3 and can be found in the appendix (Tables 67 - 78). There were no significant differences found between outcome status for the three outcomes assessed.

Final Logistic Regression Models – Aim 3

Unadjusted Models – Aim 3

Table 13 shows the unadjusted logistic regression models of <u>anxiety problems</u> for Aim 3. The unadjusted model for copper was significant (p-value=0.04). The OR=5.44, meaning that children with high copper body burden levels had 5.44 times the odds of anxiety problems than children with low copper body burden levels.

Table 13. Unadjusted Modeling of Anxiety Problems for Aim 3

Models	Exposure vs Reference	OR	95% CI	p-value
Arsenic	Present vs Absent	<0.01	<0.01 - >999.99	0.98
Manganese	Present vs Absent	3.27	0.78 - 13.74	0.11
Titanium	Present vs Absent	1.03	0.27 - 3.95	0.96
Aluminum	High vs Low	1.66	0.42 - 6.50	0.47
Chromium	High vs Low	1.03	0.27 - 3.95	0.96
Copper	High vs Low	5.44	1.06 - 27.86	0.04
Iron	High vs Low	1.66	0.42 - 6.50	0.47
Nickel	High vs Low	1.03	0.27 - 3.95	0.96
Zinc	High vs Low	1.11	0.29 - 4.23	0.88

Similar tables of unadjusted logistic regression models of investigated exposures by withdrawn/depressed and anxious/depressed problems for Aim 3 can be found in the appendix (Tables 79 - 80). Copper was statistically significant in the unadjusted models of withdrawn/depressed and anxious/depressed problems (95% CI: 1.32-95.29, p-value=0.03 and 95% CI: 1.56-110.41, p-value=0.02, respectively). Children with high copper body burden levels have 11.2 times the odds of withdrawn/depressed problems than children with low copper body burden levels. Similarly, children with high copper body burden levels have 13.1 times the odds of anxious/depressed problems than children with low copper body burden levels.

Simple Regression Analyses for Purposeful Selection Models – Aim 3

Table 14 displays the variables that were found to be liberally significant (p-value <0.20) through simple logistic regression analyses for each outcome assessed in Aim 3. Gender and mom’s depression status was liberally significant (p-value=0.17 and p-value=0.06, respectively) and therefore included in subsequent purposeful selection multiple logistic regression models of anxiety problems for Aim 3. A complete list of simple logistic regression analyses by outcome can be found in Tables 81 – 83 in the appendix.

Table 14. Variables Identified by Simple Regression Analyses for Aim 3

Variables	OR	95% CI	p-value
Anxiety Problems			
Gender (F vs M)	0.36	0.09 - 1.54	0.17
Mom Depression (Yes vs No)	3.83	0.95 - 15.44	0.06
Withdrawn/Depressed Problems			
Age	1.25	0.90 - 1.73	0.19
Mom Depression (Yes vs No)	2.83	0.66 - 12.09	0.16
Anxious/Depressed Problems			
Age	1.26	0.92 - 1.72	0.16
SES_cat (0 vs 2)	3.67	0.66 - 20.42	0.14
SES_cat (1 vs 2)	1.16	0.15 - 9.03	0.89
Mom Depression (Yes vs No)	3.83	0.95 - 15.44	0.06
Mom Anxiety (Yes vs No)	2.87	0.73 - 11.30	0.13

Age (p-value=0.19) and mom's depression status (p-value=0.16) were included as variables of interest in the purposeful selection multiple logistic regression models of withdrawn/depressed problems for Aim 3. Finally, age (p-value=0.16), SES category (p-value=0.14, 0 vs. 2), mom's depression status (p-value=0.06) and mom's anxiety status (p-value=0.13) were identified through simple logistic regression analyses of anxious/depressed problems and included in the subsequent purposeful selection multiple logistic regression models of anxious/depressed problems for Aim 3. Additionally, variables that were significantly different between exposure status in the demographic tables and cleaning tables were considered in the purposeful selection multiple logistic regression models of the corresponding exposure. These are as follows: titanium: gender and age; chromium: frequency the windows were kept open in the home; iron: frequency of smoking inside the home; and zinc: gender and frequency of wet methods used to clean the home.

Purposeful Selection Models of Anxiety – Aim 3

Table 15 shows the final purposeful selection adjusted logistic regression models of anxiety problems for Aim 3. Manganese in the corresponding adjusted model was significant (p-value=0.02). The odds of having anxiety problems are 9.03 times greater for children with high manganese body burden levels when compared to children with low manganese body burden levels. Copper was also significant in the adjusted model (p-value=0.02). The odds of having anxiety problems are 10.3 times greater for children with high copper body burden levels than children with low copper body levels. Mom's depression status was significant in all models; the odds of having anxiety problems were significantly greater for children with depressed mothers when compared to children without depressed mothers.

Table 15. Adjusted Modeling of Anxiety Problems for Aim 3

Variables	AOR	95% CI	p-value
Arsenic Model			
Arsenic (Present vs Absent)	<0.01	<0.01 - >999.99	0.98
Mom Depression (Yes vs No)	4.72	1.08 - 20.62	0.04
Gender (F vs M)	0.30	0.06 - 1.37	0.12
Manganese Model			
Manganese (Present vs Absent)	9.03	1.40 - 58.41	0.02
Mom Depression (Yes vs No)	7.60	1.34 - 43.21	0.02
Gender (F vs M)	0.28	0.05 - 1.63	0.16
Age	1.42	0.92 - 2.19	0.11
Titanium Model			
Titanium (Present vs Absent)	1.34	0.29 - 6.17	0.71

Mom Depression (Yes vs No)	5.29	1.14 - 24.64	0.03
Gender (F vs M)	0.37	0.07 - 1.82	0.22
Age	1.25	0.86 - 1.81	0.24
Aluminum Model			
Aluminum (High vs Low)	1.77	0.41 - 7.60	0.44
Mom Depression (Yes vs No)	4.81	1.08 - 21.37	0.04
Gender (F vs M)	0.26	0.06 - 1.25	0.09
Chromium Model			
Chromium (High vs Low)	1.05	0.25 - 4.38	0.94
Mom Depression (Yes vs No)	4.72	1.08 - 20.70	0.04
Gender (F vs M)	0.28	0.06 - 1.29	0.10
Copper Model			
Copper (High vs Low)	10.30	1.53 - 69.26	0.02
Mom Depression (Yes vs No)	8.73	1.49 - 51.04	0.02
Gender (F vs M)	0.23	0.04 - 1.20	0.08
Iron Model			
Iron (High vs Low)	1.51	0.31 - 7.21	0.61
Mom Depression (Yes vs No)	4.94	1.08 - 22.62	0.04
Gender (F vs M)	0.25	0.05 - 1.21	0.09
Freq of Smoking in the Home (Rarely-Frequently vs Never)	0.61	0.05 - 7.93	0.70
Nickel Model			
Nickel (High vs Low)	1.40	0.32 - 6.00	0.66
Mom Depression (Yes vs No)	5.00	1.11 - 22.56	0.04
Gender (F vs M)	0.26	0.06 - 1.26	0.09
Zinc Model			
Zinc (High vs Low)	1.23	0.27 - 5.66	0.79
Mom Depression (Yes vs No)	4.56	1.03 - 20.25	0.05
Gender (F vs M)	0.26	0.05 - 1.31	0.10

Propensity Score Models of Anxiety – Aim 3

Table 16 shows the results of the logistic regression adjusted propensity score models of anxiety problems for Aim 3. Covariates in each propensity score model include: age, gender race, SES category, parents' marriage status, mom's depression status, frequency of smoking in the home, and frequency of cleaning the entire home each week. Tables displaying the parameter estimates, standard errors, ORs, 95% confidence intervals, and p-values for each covariate by outcome for Aim 3 can be found in the appendix (Table 84). Copper body burden exposure in the copper propensity score model was significant (p-value=0.03). The odds of having anxiety problems are 6.81 times greater for those exposed to high copper body burden levels than those exposed to low copper body burden levels. Similarly to the adjusted purposeful selection models, manganese approached statistical significance in the propensity score adjusted model (AOR=4.44, p-value=0.07).

Table 16. Anxiety Problems Propensity Score Modeling for Aim 3

Model	AOR	95% CI	p-value
Nail Metal Score	0.93	0.18 - 4.76	0.93
Arsenic (Present vs Absent)	<0.01	<0.01 - >999.99	0.98
Manganese (Present vs Absent)	4.44	0.09 - 21.95	0.07
Titanium (Present vs Absent)	1.19	0.27 - 5.18	0.82
Aluminum (High vs Low)	1.66	0.42 - 6.67	0.47
Chromium (High vs Low)	1.01	0.26 - 3.91	0.99
Copper (High vs Low)	6.81	1.19 - 38.84	0.03
Iron (High vs Low)	1.77	0.43 - 7.28	0.43
Nickel (High vs Low)	1.07	0.28 - 4.13	0.92
Zinc (High vs Low)	1.23	0.29 - 5.18	0.78

Purposeful Selection Models of Withdrawn/Depressed – Aim 3

Table 17 shows the final purposeful selection adjusted logistic regression models of withdrawn/depressed problems for Aim 3. Copper was significant in the adjusted model (p-value=0.01). The odds of having withdrawn/depressed problems are 21.7 times greater for children with high copper body burden levels than children with low copper body burden levels.

Table 17. Adjusted Modeling of Withdrawn/Depressed Problems for Aim 3

Variables	AOR	95% CI	p-value
Arsenic Model			
Arsenic (Present vs Absent)	4.52	0.33 - 62.85	0.26
Mom Depression (Yes vs No)	4.15	0.84 - 20.61	0.08
Age	1.38	0.95 - 2.01	0.09
Manganese Model			
Manganese (Present vs Absent)	1.84	0.29 - 11.70	0.52
Mom Depression (Yes vs No)	4.17	0.84 - 20.70	0.08
Age	1.40	0.95 - 2.06	0.09
Titanium Model			
Titanium (Present vs Absent)	1.68	0.37 - 7.69	0.50
Mom Depression (Yes vs No)	3.83	0.79 - 18.53	0.10
Age	1.39	0.96 - 2.02	0.08
Aluminum Model			
Aluminum (High vs Low)	0.49	0.11 - 2.29	0.37
Mom Depression (Yes vs No)	3.89	0.81 - 18.79	0.09
Age	1.33	0.92 - 1.92	0.13
Chromium Model			
Chromium (High vs Low)	0.31	0.05 - 1.80	0.19
Mom Depression (Yes vs No)	3.82	0.76 - 19.09	0.10
Age	1.31	0.89 - 1.91	0.17
Windows Open (Sometimes or More vs Never or Rarely)	0.69	0.14 - 3.46	0.65
Copper Model			
Copper (High vs Low)	21.72	1.96 - 240.69	0.01
Mom Depression (Yes vs No)	9.04	1.24 - 66.14	0.03
Age	1.40	0.97 - 2.04	0.08
Iron Model			
Iron (High vs Low)	0.51	0.11 - 2.38	0.39
Mom Depression (Yes vs No)	4.00	0.83 - 19.34	0.09
Age	1.34	0.92 - 1.95	0.13
Nickel Model			
Nickel (High vs Low)	2.68	0.54 - 13.39	0.23
Mom Depression (Yes vs No)	4.94	0.92 - 26.58	0.06

Age	1.35	0.94 - 1.95	0.10
Zinc Model			
Zinc (High vs Low)	1.61	0.33 - 8.00	0.56
Mom Depression (Yes vs No)	5.20	1.11 - 24.35	0.04
Age	1.26	0.87 - 1.83	0.22
Gender (F vs M)	0.33	0.06 - 1.75	0.20

Propensity Score Models of Withdrawn/Depressed – Aim 3

Table 18 shows the results of the logistic regression adjusted propensity score models of withdrawn/depressed problems for Aim 3. Copper body burden exposure in the copper propensity score model was significant (p-value=0.01). Children with high copper body burden levels have 18.8 times the odds of withdrawn/depressed problems than children with low copper body burden levels.

Table 18. Withdrawn/Depressed Problems Propensity Score Modeling for Aim 3

Model	AOR	95% CI	p-value
Nail Metal Score	0.88	0.16 - 4.71	0.88
Arsenic (Present vs Absent)	3.41	0.27 - 43.00	0.34
Manganese (Present vs Absent)	1.48	0.25 - 8.91	0.67
Titanium (Present vs Absent)	1.91	0.38 - 9.52	0.43
Aluminum (High vs Low)	0.47	0.11 - 2.09	0.32
Chromium (High vs Low)	0.22	0.04 - 1.22	0.08
Copper (High vs Low)	18.78	1.79 - 196.59	0.01
Iron (High vs Low)	0.49	0.11 - 2.24	0.36
Nickel (High vs Low)	2.46	0.55 - 10.99	0.24
Zinc (High vs Low)	3.64	0.70 - 19.06	0.13

Purposeful Selection Models of Anxious/Depressed – Aim 3

Table 19 displays the final purposeful selection adjusted logistic regression models of anxious/depressed problems for Aim 3. Both manganese and copper were significant in their respective models (p-value=0.01 and p-value=0.01, respectively). The odds of being anxious/depressed are 8.72 times greater for children with high manganese body burden levels when compared to children with low manganese body burden levels. Children with high copper body burden levels have 52.1 times the odds of anxious/depressed problems than children with low copper body burden levels. Mom's depression status was significant in every model expect for the zinc model. Age was a significant covariate in the manganese, titanium, and copper models.

Table 19. Adjusted Modeling of Anxious/Depressed Problems for Aim 3

Variables	AOR	95% CI	p-value
Arsenic Model			
Arsenic (Present vs Absent)	<0.01	<0.01 - >999.99	0.98
Mom Depression (Yes vs No)	5.61	1.20 - 26.26	0.03
Age	1.39	0.96 - 2.02	0.08
Manganese Model			
Manganese (Present vs Absent)	8.72	1.39 - 54.71	0.02
Mom Depression (Yes vs No)	8.91	1.50 - 52.96	0.02
Age	1.70	1.09 - 2.65	0.02
Titanium Model			
Titanium (Present vs Absent)	2.22	0.49 - 10.10	0.30
Mom Depression (Yes vs No)	5.68	1.18 - 27.41	0.03
Age	1.47	1.01 - 2.15	0.05
Aluminum Model			
Aluminum (High vs Low)	1.21	0.28 - 5.16	0.80
Mom Depression (Yes vs No)	5.85	1.23 - 27.87	0.03
Age	1.42	0.98 - 2.05	0.07
Chromium Model			
Chromium (High vs Low)	1.43	0.26 - 7.97	0.69
Mom Depression (Yes vs No)	6.75	1.18 - 38.51	0.03
Age	1.45	0.98 - 2.16	0.07
SES (0 vs 2)	3.20	0.50 - 20.41	0.22
SES (1 vs 2)	0.52	0.04 - 6.69	0.62
Windows Open (Sometimes or	0.42	0.07 - 2.55	0.35

More vs Never or Rarely)			
Copper Model			
Copper (High vs Low)	52.13	2.96 - 919.72	0.01
Mom Depression (Yes vs No)	28.03	1.67 - 469.45	0.02
Age	1.57	1.01 - 2.43	0.04
SES (0 vs 2)	3.92	0.46 - 33.56	0.21
SES (1 vs 2)	0.62	0.03 - 12.69	0.75
Iron Model			
Iron (High vs Low)	1.29	0.25 - 6.72	0.77
Mom Depression (Yes vs No)	8.90	1.37 - 57.85	0.02
Age	1.49	0.99 - 2.23	0.05
SES (0 vs 2)	4.10	0.59 - 28.63	0.15
SES (1 vs 2)	0.56	0.05 - 6.55	0.64
Freq of Smoking in the Home (Rarely-Frequently vs Never)	<0.01	<0.01 - >999.99	0.97
Nickel Model			
Nickel (High vs Low)	2.03	0.44 - 9.37	0.36
Mom Depression (Yes vs No)	6.87	1.32 - 35.80	0.02
Gender (F vs M)	1.41	0.98 - 2.03	0.07
Zinc Model			
Zinc (High vs Low)	3.21	0.60 - 17.24	0.17
Mom Depression (Yes vs No)	4.40	0.85 - 22.70	0.08
Age	1.42	0.94 - 2.14	0.10
Gender (F vs M)	0.58	0.12 - 2.90	0.50
Wet Cleaning (Freq vs Not Freq)	0.44	0.07 - 2.67	0.37

Propensity Score Models of Anxious/Depressed – Aim 3

Table 20 shows the results of the logistic regression adjusted propensity score models of anxious/depressed problems for Aim 3. Copper body burden exposure was significant in the corresponding model (p-value=0.02). Children with high copper body burden levels have 15.0 times the odds of anxious/depressed problems than children with low copper body burden levels.

Table 20. Anxious/Depressed Problems Propensity Score Modeling for Aim 3

Model	AOR	95% CI	p-value
Nail Metal Score	1.20	0.15 - 9.74	0.86
Arsenic (Present vs Absent)	<0.01	<0.01 - >999.99	0.98
Manganese (Present vs Absent)	3.69	0.78 - 17.36	0.10
Titanium (Present vs Absent)	1.74	0.39 - 7.75	0.47
Aluminum (High vs Low)	0.97	0.25 - 3.77	0.97
Chromium (High vs Low)	0.64	0.16 - 2.52	0.53
Copper (High vs Low)	15.03	1.66 - 136.11	0.02
Iron (High vs Low)	0.98	0.25 - 3.89	0.98
Nickel (High vs Low)	1.68	0.43 - 6.63	0.46
Zinc (High vs Low)	1.83	0.43 - 7.81	0.42

DISCUSSION

Anxiety problems in this study ranged from 14.5-16.5%, withdrawn/depressed problems ranged from 13.0-15.2%, and anxious/depressed problems ranged from 14.5-19.0%. Children in this study were more likely to have anxiety compared with children in other populations. Literature suggests that an estimated 8-12% of children meet the criteria for an anxiety disorder severe enough to impact day-to-day life (123). In addition, children in this study were on the high-end of the reported prevalence of depression. Prevalence of depression in children reported in the literature ranges from 0.2% to 17%, while the median is about 4% (128). Internalizing behaviors, such as anxiety and depression, are not as evident as externalizing behaviors and may be underreported (164), so this study may underreport anxiety and depression as well. When pediatric emotional problems go unaddressed, problems can persist into adulthood, making anxiety and depression problems in children a public health concern, and thus, it is important to identify at risk populations. Pathophysiological processes for anxiety and depression are not completely understood. Only a few studies have begun to assess the role of metal exposure in behavioral and emotional problems in children (93-95, 165).

Literature that examines the health effects of CCR like coal ash, and fly ash in particular, in communities surrounding coal-fired power plants and coal ash storage facilities is lacking. Populations residing near coal ash storage facilities are likely exposed to PM_{10} that has higher concentrations of metals. A study by Tang et al. (2013), evaluating the potential ecological and children's health risk in the area surrounding a coal-fired power plant, reported that soil samples downwind of the plant had elevated concentrations of arsenic, cadmium, chromium, copper, lead, manganese, nickel, and zinc when compared to soil samples up wind of the plant (43). While several metals are needed in trace amounts for essential physiological functions, a building body of literature has determined that excess exposure to certain metals can be toxic and lead to disease (165).

This study sought to examine the relationship between PM_{10}, fly ash, and various metal exposures and pediatric anxiety and/or depression problems. While the sample size was limiting, high exposure levels of copper and the presence of manganese in the body proved to be significant. The strength of an epidemiological association is dependent upon consistency in the literature. The literature is lacking with respect to coal ash and human health, and for this reason the results of this study are interpreted with caution.

Findings

Copper in Filter and Nail Samples

In this study, copper was significant in several models. High copper levels in the home environment were significantly associated with anxious/depressed problems in the unadjusted logistic regression model (OR=3.54, CI: 1.02-12.30, p-value=0.05). Though significance was lost in the adjusted models, we suspect filter copper levels to be of interest when more participants are added to the study and the power increases.

Copper body burden was significant in both modeling techniques (purposeful selection and propensity score models) for each outcome explored in Aim 3: anxiety problems, withdrawn/depressed problems, and anxious/depressed problems. High copper body burden levels were significantly associated with anxiety problems (AOR=6.81, 95%

CI: 1.19-38.8, p-value =0.03 in the propensity score model and AOR=10.3, 95% CI: 1.53-69.3, p-value=0.02 in the purposeful selection model). Likewise, high copper body burden levels were significantly associated with withdrawn/depressed problems (AOR=18.8, 95% CI: 1.79-197, p-value =0.01 in the propensity score model and AOR=21.7, 95% CI: 1.96-240, p-value=0.01 in the purposeful selection model). Furthermore, high copper body burden levels were significantly associated with anxious/depressed problems (AOR=15.0, 95% CI: 1.66-136, p-value =0.02 in the propensity score model and AOR=52.1, 95% CI: 2.96-919, p-value=0.01 in the purposeful selection model). In these findings, it is likely that the propensity score models are more conservative, as they are conditioned on more variables than the purposeful selection models. It is also important to consider the exposure used to create the continuous propensity score, the total nail metal score. Both of these factors could contribute to the differences in AOR. Nevertheless, both models demonstrate that, in this study, children with high copper body burden had higher odds of anxiety and/or depression problems when compared to children with low copper body burdens.

Though copper is needed in trace amounts for proper iron absorption and heme synthesis, too much copper in the body has been linked to adverse health effects including nervousness, irritability, and depression (79, 165). In a study examining the impact of copper in patients with Parkinson's disease, free copper was associated with an increase in oxidative stress (166). Parkinson's disease is neurological disorder not unlike anxiety and depression problems, which have also been associated with oxidative stress (109, 110, 120). Alternatively, research suggests that excess copper can alter the function of gamma aminobutyric acid (GABA), possibly interfering with the conversion of glutamate to GABA (165). Both glutamate and GABA neurotransmitter dysfunction have been reported in anxiety and depression (167, 168). Copper is also known to inhibit the production of serotonin, which has been linked to depressive disorders (165). Though the mechanisms are not quite clear, it is evident that excess levels of copper in the body may play an important role in several pathways that lead to harmful neurological outcomes.

Manganese in Nail Samples

Presence of manganese in the body was significant in two of the purposeful selection models explored in Aim 3. This study showed that children with manganese present in their body were more likely to have anxiety and anxious/depressed problems compared to children with no manganese present (AOR=9.03, 95% CI: 1.40-58.4, p-value=0.02 and AOR=8.72, 95% CI: 1.39-54.7, p-value=0.02, respectively).
In addition to these findings, another study using preliminary data from the overarching study reported a significant relationship between manganese exposure and neurobehavioral function; presence of manganese in children's nails was significantly associated with abnormal Visual-Motor Integration scores determined from Berry-VMI tests (p-value=0.002) (169).

Similarly to copper, manganese is required for several physiological processes but can be toxic in excess amounts (91). Excess levels of manganese cause a neurological condition known as manganism, a term used to describe the parkinsonian-like syndrome that results from manganese poisoning (92). It is known to cause motor and cognitive deficits, as well as decreased psychiatric health (91). Current literature focuses on the role manganese plays in dopamine neurotransmission. Specifically, a growing body of evidence suggests excess exposure levels are associated with post-synaptic dopamine D2 receptor (D2R2) dysfunction (92). Research is also investigating the role of manganese in the GABA and glutamate neurotransmitter systems (170). While these mechanisms are not fully understood, dysfunction of these neurotransmitters have been implicated in anxiety and depressive disorders (167, 168). More studies, both animal and human, are needed to further understand the link between excess manganese exposure and emotional problems, particularly in children.

Filter Metal Score

The filter metal score, which was created by ranking each participant's exposure to the corresponding metal and then summing up the scores, was significant in the propensity score model of withdrawn/depressed problems. High filter metal score had an AOR=0.14 (95% CI: 0.03-0.80, p-value=0.03), suggesting children with low filter metal scores, or low metal exposure in their home environment, had increased odds of withdrawn/depressed problems when compared to children with high filter metal scores. This relationship may contradict other findings and may seem intuitively problematic. This relationship should be examined further before making concrete interpretations. This finding suggests that metal interactions, particularly among essential elements, might be an important next step in assessing the relationship between metal exposure and anxiety and/or depression problems. Furthermore, as previously described in the literature review, several of the metals being investigated are problematic for health at both low and high levels. When more data becomes available, it might be useful to examine tertile levels of the total filter metal score.

Fly Ash

Fly ash may cause neurobehavioral symptoms and problems. These small particles that contain elements and metals have the ability to enter the bloodstream through the lung. In both the purposeful selection model and propensity score model of anxiety problems, the adjusted odds ratio for fly ash was elevated, AOR=1.32 and AOR=1.33, though not significant (95% CI: 0.35-5.06, p-value=0.68 and 95% CI: 0.21-4.04, p-value=0.91, respectively). The AOR was also elevated in the propensity score model of withdrawn/depressed problems (AOR=1.12, 95% CI: 0.28-4.47, p-value=0.88). In addition to these findings, another study using preliminary data from the overarching study reported elevated adjusted odds ratios between fly ash and neurobehavioral function tests (169). These relationships need to be reevaluated as the sample size and power increase in the overarching study.

Mom's Depression Status

Maternal depression was not a main exposure investigated in this study, but based on previous literature and demographic analyses it was adjusted for in every model (137, 138). It was significantly associated with the respective outcome in 48.5% of the purposeful selection models in Aims 1 and 2 (16 of 33 models), and significantly associated with the respective outcome in 77.8% of the purposeful selection models in Aim 3 (21 of 27 models). Several reports have highlighted the significant association between maternal depression and higher levels of mood disorders and other internalizing behaviors (137). However, the strength of the association and potential moderators are not well understood.

In this study the odds ratio for maternal depression in the purposeful selection model of copper and anxious/depressed problems exceeded 28 (95% CI: 1.67-469, p-value=0.04). While the distribution was not significantly different, 11 children with depressed mothers had low nail copper levels compared to 6 children with depressed mothers that had high nail copper levels. This could suggest that mom's depression status and nail copper levels are inversely associated. Hyper inflated AOR could result from the negative correlation. In general, maternal depression status remains of interest in the development of child psychopathologies and should be studied in further depth.

Strengths of the Study

This is the first study to comprehensively assess the impacts of PM_{10}, fly ash, and metal exposure, both home environment and body burden, on pediatric anxiety and/or depression. Furthermore, to date, only a few studies exist that examine the relationship between metal exposure and CBCL outcomes. In this respect, this study seeks to improve current understanding about environmental exposures that could impact pediatric anxiety and/or depression.

The unique exposure assessment design was also a strength in this study. In-home exposures, including PM_{10}, fly ash, and various metals were collected using personal air sampling pumps. Nail samples were also utilized as a biomarker to evaluate various metal body burdens.

Another strength of this study is the community-based design, which allows us to conveniently sample the target population. In addition, the use of community leaders has helped recruitment, as the leaders are familiar with their neighborhoods. Research has shown that working with the community increases recruitment and retention in studies

(171-173). Furthermore, all consenting, sampling, and testing is performed in the participant's home, which may increase participation and retention.

Additionally, the study population is unique in that there are two coal ash storage facilities and they are located just miles apart. The overarching study will ultimately take distance from the plants and wind pattern into account.

Limitations of the Study

There are several limitations to consider when interpreting the results of this study. The first limitation to discuss is the sample size, which is affected by various factors. While the overarching study has received funding for 5 years and anticipates a final sample size of 300, the current study is preliminary and reflects results collected for participants in the first 1.33 years of the study (September 2015- January 2017). In addition, sample size is also affected by the nature of our study design, community-based participatory research. Response rates from door-to-door and mail recruiting have been low and recruitment more difficult than expected. Despite this, the overarching study has enrolled 70% of the projected participants at this point in the study period. Nail collection can be lengthy, which also affects the sample size. The collection time can range from 3 weeks to over a year, depending on the participant's willingness and response. And finally, lab analysis can be lengthy. Elemental Lab Analyses, Inc. was contracted to perform PIXE and SEM/EDX on filters and nail samples, a costly procedure. In an effort to cut back on costs, samples are sent and tested in bulk creating a lag between sample collection, testing, and results. Furthermore, while the lab attempts to return samples within 10 days of receiving the samples, turnaround times can range from 10 days to 2.5 months.

The small sample size of this study affected the interpretation of several variables including race, filter chromium, and nail arsenic. Each of these variables had low cell counts, making the odds ratio difficult to interpret. For example, only three participants had detectable arsenic in their nails, but no child had detectable nail arsenic and anxiety problems. Therefore, an odds ratio calculation was essentially dividing a numerator of zero yielding an odds ratio and confidence interval that was hard to interpret. These problems should dissipate as the sample size increases.

Since the overarching study was not specifically designed to assess pediatric anxiety and/or depression, not all potential covariates were collected. These include a direct measure of SES and sleep behaviors in children. In order to estimate SES, an indirect measure using block census data was collected and categorized. The role of SES in pediatric anxiety and depression problems is still not definitive, but a direct measure might be an important covariate in the relationship between metal exposure and pediatric anxiety and/or depression.

Recent studies have shown that sleep quality in children is negatively associated with self-reported anxiety and depression issues (174). Because the current study did not collect information on time to bed or sleep quality, we are unable to investigate this as a potential covariate. In the initial pilot study, investigators collected information on sleep disruptive behaviors and found a significant association between sleep disruptive behaviors that affect maintenance of sleep and coal ash exposure (p-value <0.001) (175). Together, these pieces of information suggest that coal ash is associated with sleep disorders, which could play a role in or modify the association of coal ash and anxiety and/or depression problems.

A third limitation is the limit of detection (LOD) of PIXE. Elements we would expect to find in this population, such as lead, mercury, and cadmium, were not detected and likely below the LOD set by PIXE. While PIXE is a good analytical method for assessing low concentrations, some of these elements may be present in “trace” amounts, making detection difficult. Further studies should investigate “trace” amounts using different analytical analysis.

The final limitation of this piece of the overarching study is that it is unable to determine definitively whether high copper, manganese, and other metal levels can be attributed to coal ash exposure. While coal ash is a probable exposure source, exposure could too come from other air pollution in the Louisville area. This will be examined in additional studies as the sample size grows.

Future Studies

As the sample size increases in the overarching study, more analyses will be conducted in this area to reassess the relationships between PM_{10}, fly ash, and metal exposure and anxiety and/or depression problems. However, in general more research is needed to evaluate the effects on coal ash. Initially, this study proposed to look at tertile levels of exposure, primarily because several of the investigated metals have been known to cause adverse health effects at both low and high levels. For example, zinc is an element that both too little and too much can cause adverse health effects. Some literature has been published on zinc deficiency’s role in maternal and pediatric depression, while other literature has found associations between elevated zinc exposure and increased behavioral problems on eight subscales of the CBCL. Bao et al. (2009) reported that higher concurrent log-transformed hair zinc levels increased behavioral problems on all subscales examined, including withdrawn/depressed and anxious/depressed. Therefore, examining tertile levels of exposure where the middle exposure level serves as a reference against low and high levels of exposure might be advantageous. However, the current study was limited in regards to the amount of data observations available.

In addition to CBCL outcomes, future studies could investigate various exposures and their relationship with structured clinical diagnoses. As previously described, follow up interviews are completed for children who have a CBCL t-score ≥65, further evaluating children with t-scores that fall in the borderline or clinically significant range. The interviews are conducted using the MINI-KID International Neuropsychiatric Interview for Children and Adolescents, version 6.0. As the sample grows, this outcome could help further assess associations between various exposures and clinically diagnosable outcomes.

In the overarching study, five participants from each sampling unit are being recruited in each of the four seasons. Ultimately, seasonal effects of pediatric anxiety and/or depression could be examined. While seasonal affective disorder is more commonly reported in adults, symptom onset my occur during childhood (176).

Furthermore, the overarching study takes in to account distance from the plants. Future studies could assess metal exposure and fly ash exposure, both in the home environment and body burden, by distance from the power plants and coal ash storage facilities. Distance from the plant would also be interesting to look at in relation to anxiety and/or depression problems, investigating whether children who live closer to the plant have higher odds of anxiety and/or depression problems than children who live further from the plant.

Finally, future studies are needed to assess this relationship in other populations. For example, assessing the relationship between PM_{10}, fly ash, and metal exposure and pediatric anxiety and/or depression problems in other populations residing near coal ash storage facilities would be useful in comparing the results from the current study. Furthermore, assessing the relationship between PM_{10} and metal exposure and pediatric anxiety and/or depression problems in a matched cohort study, children exposed to coal ash matched by age, race, and gender with unexposed children, would be useful in determining if excess PM_{10} and metal exposure may be attributed to coal ash exposure. Measuring metal concentrations in the nails of healthy children would also contribute greatly to the limited data that currently exists.

CONCLUSION

Not only are coal-burning power plants a likely source of airborne particulate matter, but the particulate matter emitted from coal-burning plants have increased concentrations of toxic elements (101). Populations that surround coal-burning power plants and coal ash storage facilities are understudied; the overarching study is one of the first to investigate the effects of coal ash on children's neurobehavioral health. The current study is one of the first to comprehensively assess the relationship between PM_{10}, fly ash, and metal exposure, both in-home environment and body burden, on pediatric anxiety and/or depression. While the preliminary sample size was limited, high levels of copper and manganese presence proved to be of interest. High copper body burden was significantly associated with all three outcomes (anxiety problems, withdrawn/depressed problems, and anxious/depressed problems) in purposeful selection and propensity score models. Manganese present in the body was significantly associated anxiety and anxious/depressed problems in the purposeful selection models. The findings of this study demonstrate the dire need to investigate the health effects of coal ash. Children are of particular concern due to their still developing respiratory and neurological systems. The EPA estimates that 1.5 million children nationwide live near coal ash storage facilities (177). Future epidemiological studies are charged with further assessing the health effects of coal ash, in both similar and dissimilar populations. Furthermore, internalizing behaviors, such as anxiety and depression, are not as evident as externalizing behaviors (164). Therefore, targeting at risk populations to test for anxiety and/or depression will help better assess the true size of the issue. More complete information will help drive intervention and policy that can drive change.

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APPENDIX

Table 21. Demographics by Withdrawn/Depressed Problems for Aims 1 and 2

	Withdrawn/Depressed Problems (N=79)				
	t-score <65		t-score ≥ 65		
	Count (N=67)	Percent[A]	Count (N=12)	Percent[A]	p-value
Sex					0.886
Male	35	52%	6	50%	
Female	32	48%	6	50%	
Age					0.362[B]
6-8 years	18	27%	1	8%	
9-11 years	19	28%	3	25%	
12-14 years	30	45%	8	67%	
Race					0.168[B]
White	48	72%	12	100%	
African American	16	24%	0	0%	
AI/AN	2	3%	0	0%	
Asian	1	1%	0	0%	
SES					0.493[B]
Low	23	34%	6	50%	
Middle	22	33%	2	17%	
High	22	33%	4	33%	
Parents' Marriage Status					0.483
Married	46	69%	7	58%	
Unmarried	21	31%	5	42%	
Smoking in the Home					0.443[B]
No	55	82%	9	75%	
Yes	11	16%	3	25%	
Freq of Smoking in Home					0.647[B]
None	58	87%	10	83%	
Rarely-Frequently	8	12%	2	17%	
Mom Anxiety					0.491[B]
No	44	66%	9	75%	
Yes	20	30%	2	17%	
Mom Depression					0.063
No	47	70%	5	42%	
Yes	17	25%	6	50%	

A. Numbers may not add to 100% due to rounding or missing data.

B. Fisher's Exact p-value.

Table 22. Demographics by Anxious/Depressed Problems for Aims 1 and 2

	Anxious/Depressed Problems (N=79)				
	t-score <65		t-score ≥ 65		
	Count (N=64)	Percent[A]	Count (N=15)	Percent[A]	p-value
Sex					0.902
Male	33	52%	8	53%	
Female	31	48%	7	47%	
Age					0.573[B]
6-8 years	17	27%	2	13%	
9-11 years	17	27%	5	33%	
12-14 years	30	47%	8	53%	
Race					0.429[B]
White	46	72%	14	93%	
African American	15	23%	1	7%	
AI/AN	2	3%	0	0%	
Asian	1	2%	0	0%	
SES					0.767[B]
Low	22	34%	7	47%	
Middle	20	31%	4	27%	
High	22	34%	4	27%	
Parents' Marriage Status					0.9692
Married	43	67%	10	67%	
Unmarried	21	33%	5	33%	
Smoking in the Home					1.000[B]
No	52	81%	12	80%	
Yes	11	17%	3	20%	
Freq of Smoking in Home					0.195[B]
None	53	83%	15	100%	
Rarely-Frequently	10	16%	0	0%	
Mom Anxiety					0.427
No	45	70%	8	53%	
Yes	17	27%	5	33%	
Mom Depression					0.046
No	46	72%	6	40%	
Yes	16	25%	7	47%	

A. Numbers may not add to 100% due to rounding or missing data.

B. Fisher's Exact p-value.

Table 23. Contingency Table of Outcomes for Aims 1 and 2

		AD = 0	AD = 1	Total
A = 0	W/D = 0	59	3	62
	W/D = 1	3	1	4
A = 1	W/D = 0	1	4	5
	W/D = 1	1	7	8
	Total	64	15	79

Table 24. Cleaning Behaviors by Withdrawn/Depressed Problems for Aims 1 and 2

	Withdrawn/Depressed Problems				
	t-score <65		t-score ≥ 65		
	Count (N=67)	Percent[A]	Count (N=12)	Percent[A]	p-value
How frequently do you keep the windows open?					0.034
Never or Rarely	18	27%	7	58%	
Sometimes, Frequently, or As Much As Possible	48	72%	5	42%	
How frequently do you clean your entire home?					0.722[B]
1 or Fewer Times per Week	50	75%	10	83%	
2-7 Times per Week	16	24%	2	17%	
How frequently are wet methods used to clean your home?					0.110[B]
1 or Fewer Times per Week	37	55%	10	83%	
2-7 Times per Week	29	43%	2	17%	
How frequently are dry methods used to clean your home?					0.108[B]
1 or Fewer Times per Week	36	54%	10	83%	
2-7 Times per Week	30	45%	2	17%	

A. Numbers may not add to 100% due to rounding or missing data.

B. Fisher's Exact p-value.

Table 25. Cleaning Behaviors by Anxious/Depressed Problems for Aims 1 and 2

	Anxious/Depressed Problems				
	t-score <65		t-score ≥ 65		
	Count (N=64)	Percent[A]	Count (N=15)	Percent[A]	p-value
How frequently do you keep the windows open?					0.177
Never or Rarely	18	28%	7	47%	
Sometimes, Frequently, or As Much As Possible	45	70%	8	53%	
How frequently do you clean your entire home?					1.000[B]
1 or Fewer Times per Week	48	75%	12	80%	
2-7 Times per Week	15	23%	3	20%	
How frequently are wet methods used to clean your home?					0.380[B]
1 or Fewer Times per Week	36	56%	11	73%	
2-7 Times per Week	27	42%	4	27%	
How frequently are dry methods used to clean your home?					0.254[B]
1 or Fewer Times per Week	35	55%	11	73%	
2-7 Times per Week	28	44%	4	27%	

A. Numbers may not add to 100% due to rounding or missing data.
B. Fisher's Exact p-value.

Table 26. Demographics by Fly Ash Exposure for Aim 1

	Fly Ash (N=79)				
	Absent		Present		
	Count (N=50)	Percent[A]	Count (N=29)	Percent[A]	p-value
Sex					0.624
Male	27	54%	14	48%	
Female	23	46%	15	52%	
Age					0.506
6-8 years	14	28%	5	17%	
9-11 years	14	28%	8	28%	
12-14 years	22	44%	16	55%	
Race					0.086[B]
White	38	76%	22	76%	
African American	12	24%	4	14%	
AI/AN	0	0%	2	7%	
Asian	0	0%	1	3%	
SES					0.684
Low	20	40%	9	31%	
Middle	15	30%	9	31%	
High	15	30%	11	38%	
Parents' Marriage Status					0.223
Married	36	72%	17	59%	
Unmarried	14	28%	12	41%	
Smoking in the Home					0.900
No	40	80%	24	83%	
Yes	9	18%	5	17%	
Freq of Smoking in Home					1.000[B]
None	43	86%	25	86%	
Rarely-Frequently	6	12%	4	14%	
Mom Anxiety					0.996
No	34	68%	19	66%	
Yes	14	28%	8	28%	
Mom Depression					0.156
No	36	72%	16	55%	
Yes	12	24%	11	38%	

A. Numbers may not add to 100% due to rounding or missing data.

B. Fisher's Exact p-value.

Table 27. Demographics by Arsenic Exposure for Aim 2

	Filter Arsenic (N=79)				
	Absent		Present		
	Count (N=43)	Percent[A]	Count (N=36)	Percent[A]	p-value
Sex					0.225
Male	25	58%	16	44%	
Female	18	42%	20	56%	
Age					0.553
6-8 years	9	21%	10	28%	
9-11 years	14	33%	8	22%	
12-14 years	20	47%	18	50%	
Race					0.479[B]
White	33	77%	27	75%	
African American	9	21%	7	19%	
AI/AN	0	0%	2	6%	
Asian	1	2%	0	0%	
SES					0.669
Low	15	35%	14	39%	
Middle	12	28%	12	33%	
High	16	37%	10	28%	
Parents' Marriage Status					0.130
Married	32	74%	21	58%	
Unmarried	11	26%	15	42%	
Smoking in the Home					0.750
No	35	81%	29	81%	
Yes	7	16%	7	19%	
Freq of Smoking in Home					0.500[B]
None	38	88%	30	83%	
Rarely-Frequently	4	9%	6	17%	

A. Numbers may not add to 100% due to rounding or missing data.

B. Fisher's Exact p-value.

Table 28. Demographics by Chromium Exposure for Aim 2

	Filter Chromium (N=79)				
	Absent		Present		
	Count (N=66)	Percent[A]	Count (N=13)	Percent[A]	p-value
Sex					0.878
Male	34	52%	7	54%	
Female	32	48%	6	46%	
Age					0.143[B]
6-8 years	13	20%	6	46%	
9-11 years	20	30%	2	15%	
12-14 years	33	50%	5	38%	
Race					1.000[B]
White	50	76%	10	77%	
African American	13	20%	3	23%	
AI/AN	2	3%	0	0%	
Asian	1	2%	0	0%	
SES					0.866[B]
Low	24	36%	5	38%	
Middle	21	32%	3	23%	
High	21	32%	5	38%	
Parents' Marriage Status					0.266
Married	46	70%	7	54%	
Unmarried	20	30%	6	46%	
Smoking in the Home					0.110[B]
No	51	77%	13	100%	
Yes	14	21%	0	0%	
Freq of Smoking in Home					1.000[B]
None	56	85%	12	92%	
Rarely-Frequently	9	14%	1	8%	

A. Numbers may not add to 100% due to rounding or missing data.

B. Fisher's Exact p-value.

Table 29. Demographics by Manganese Exposure for Aim 2

	Filter Manganese (N=79)				
	Absent		Present		
	Count (N=45)	Percent[A]	Count (N=34)	Percent[A]	p-value
Sex					0.769
Male	24	53%	17	50%	
Female	21	47%	17	50%	
Age					0.706
6-8 years	11	24%	8	24%	
9-11 years	14	31%	8	24%	
12-14 years	20	44%	18	53%	
Race					0.661[B]
White	32	71%	28	82%	
African American	11	24%	5	15%	
AI/AN	1	2%	1	3%	
Asian	1	2%	0	0%	
SES					0.079
Low	16	36%	13	38%	
Middle	10	22%	14	41%	
High	19	42%	7	21%	
Parents' Marriage Status				0%	0.174
Married	33	73%	20	59%	
Unmarried	12	27%	14	41%	
Smoking in the Home		0%			0.066
No	40	89%	24	71%	
Yes	5	11%	9	26%	
Freq of Smoking in Home					0.308[B]
None	41	91%	27	79%	
Rarely-Frequently	4	9%	6	18%	

A. Numbers may not add to 100% due to rounding or missing data.

B. Fisher's Exact p-value.

Table 30. Demographics by Nickel Exposure for Aim 2

	Filter Nickel (N=79)				
	Absent		Present		
	Count (N=40)	Percent[A]	Count (N=39)	Percent[A]	p-value
Sex					0.576
Male	22	55%	19	49%	
Female	18	45%	20	51%	
Age					0.725
6-8 years	9	23%	10	26%	
9-11 years	10	25%	12	31%	
12-14 years	21	53%	17	44%	
Race					0.416[B]
White	29	73%	31	79%	
African American	9	23%	7	18%	
AI/AN	2	5%	0	0%	
Asian	0	0%	1	3%	
SES					0.469
Low	17	43%	12	31%	
Middle	10	25%	14	36%	
High	13	33%	13	33%	
Parents' Marriage Status					0.379
Married	25	63%	28	72%	
Unmarried	15	38%	11	28%	
Smoking in the Home					0.486
No	34	85%	30	77%	
Yes	6	15%	8	21%	
Freq of Smoking in Home					0.738[B]
None	34	85%	34	87%	
Rarely-Frequently	6	15%	4	10%	

A. Numbers may not add to 100% due to rounding or missing data.

B. Fisher's Exact p-value.

Table 31. Demographics by Aluminum Exposure for Aim 2

	Filter Aluminum Levels (N=79)				
	Low ≤ 0.0566 µg/m^3		High >0.0566 µg/m^3		
	Count (N=40)	Percent[A]	Count (N=39)	Percent[A]	p-value
Sex					0.144
Male	16	40%	22	56%	
Female	24	60%	17	44%	
Age					0.849
6-8 years	10	25%	9	23%	
9-11 years	10	25%	12	31%	
12-14 years	20	50%	18	46%	
Race					0.416[B]
White	31	78%	29	74%	
African American	9	23%	7	18%	
AI/AN	0	0%	2	5%	
Asian	0	0%	1	3%	
SES					0.019
Low	12	30%	17	44%	
Middle	9	23%	15	38%	
High	19	48%	7	18%	
Parents' Marriage Status					0.013
Married	32	80%	21	54%	
Unmarried	8	20%	18	46%	
Smoking in the Home					0.916
No	33	83%	31	79%	
Yes	7	18%	7	18%	
Freq of Smoking in Home					0.187[B]
None	37	93%	31	79%	
Rarely-Frequently	3	8%	7	18%	

A. Numbers may not add to 100% due to rounding or missing data.

B. Fisher's Exact p-value.

Table 32. Demographics by Copper Exposure for Aim 2

	Filter Copper Levels (N=79)				
	Low ≤0.0021 μg/m^3		High >0.0021 μg/m^3		
	Count (N=40)	Percent[A]	Count (N=39)	Percent[A]	p-value
Sex					0.576
Male	22	55%	19	49%	
Female	18	45%	20	51%	
Age					0.725
6-8 years	11	28%	8	21%	
9-11 years	10	25%	12	31%	
12-14 years	19	48%	19	49%	
Race					<0.001[B]
White	24	60%	36	92%	
African American	15	38%	1	3%	
AI/AN	1	3%	1	3%	
Asian	0	0%	1	3%	
SES					0.180
Low	13	33%	16	41%	
Middle	10	25%	14	36%	
High	17	43%	9	23%	
Parents' Marriage Status					0.379
Married	25	63%	28	72%	
Unmarried	15	38%	11	28%	
Smoking in the Home					0.141[B]
No	30	75%	34	87%	
Yes	10	25%	4	10%	
Freq of Smoking in Home					0.738[B]
None	34	85%	34	87%	
Rarely-Frequently	6	15%	4	10%	

A. Numbers may not add to 100% due to rounding or missing data.

B. Fisher's Exact p-value.

Table 33. Demographics by Iron Exposure for Aim 2

	Filter Iron Levels (N=79)				
	Low ≤0.0548 μg/m³		High >0.0548 μg/m³		
	Count (N=40)	Percent[A]	Count (N=39)	Percent[A]	p-value
Sex					0.144
Male	24	60%	17	44%	
Female	16	40%	22	56%	
Age					0.980
6-8 years	10	25%	9	23%	
9-11 years	11	28%	11	28%	
12-14 years	19	48%	19	49%	
Race					0.280[B]
White	30	75%	30	77%	
African American	10	25%	6	15%	
AI/AN	0	0%	2	5%	
Asian	0	0%	1	3%	
SES					0.038
Low	14	35%	15	38%	
Middle	8	20%	16	41%	
High	18	45%	8	21%	
Parents' Marriage Status					0.013
Married	32	80%	21	54%	
Unmarried	8	20%	18	46%	
Smoking in the Home					0.916
No	33	83%	31	79%	
Yes	7	18%	7	18%	
Freq of Smoking in Home					0.512[B]
None	36	90%	32	82%	
Rarely-Frequently	4	10%	6	15%	

A. Numbers may not add to 100% due to rounding or missing data.

B. Fisher's Exact p-value.

Table 34. Demographics by Titanium Exposure for Aim 2

	Filter Titanium Levels (N=79)				
	Low ≤0.0046 μg/m³		High >0.0046 μg/m³		
	Count (N=40)	Percent[A]	Count (N=39)	Percent[A]	p-value
Sex					0.576
Male	22	55%	19	49%	
Female	18	45%	20	51%	
Age					0.552
6-8 years	10	25%	9	23%	
9-11 years	9	23%	13	33%	
12-14 years	21	53%	17	44%	
Race					0.095[B]
White	28	70%	32	82%	
African American	11	28%	5	13%	
AI/AN	0	0%	2	5%	
Asian	1	3%	0	0%	
SES					0.038
Low	14	35%	15	38%	
Middle	8	20%	16	41%	
High	18	45%	8	21%	
Parents' Marriage Status					0.300
Married	29	73%	24	62%	
Unmarried	11	28%	15	38%	
Smoking in the Home					0.628
No	32	80%	32	82%	
Yes	8	20%	6	15%	
Freq of Smoking in Home					0.738[B]
None	34	85%	34	87%	
Rarely-Frequently	6	15%	4	10%	

A. Numbers may not add to 100% due to rounding or missing data.

B. Fisher's Exact p-value.

Table 35. Demographics by Zinc Exposure for Aim 2

	Filter Zinc Levels (N=79)				
	Low ≤0.0092 μg/m^3		High >0.0092 μg/m^3		
	Count (N=41)	Percent[A]	Count (N=38)	Percent[A]	p-value
Sex					0.438
Male	23	56%	18	47%	
Female	18	44%	20	53%	
Age					0.941
6-8 years	10	24%	9	24%	
9-11 years	12	29%	10	26%	
12-14 years	19	46%	19	50%	
Race					0.228[B]
White	28	68%	32	84%	
African American	11	27%	5	13%	
AI/AN	1	2%	1	3%	
Asian	1	2%	0	0%	
SES					0.456
Low	17	41%	12	32%	
Middle	10	24%	14	37%	
High	14	34%	12	32%	
Parents' Marriage Status					0.031
Married	32	78%	21	55%	
Unmarried	9	22%	17	45%	
Smoking in the Home					0.422
No	35	85%	29	76%	
Yes	6	15%	8	21%	
Freq of Smoking in Home					0.179[B]
None	38	93%	30	79%	
Rarely-Frequently	3	7%	7	18%	

A. Numbers may not add to 100% due to rounding or missing data.

B. Fisher's Exact p-value.

Table 36. Cleaning Behaviors by PM_{10} Exposure for Aim 1

	PM10 Levels (N=79)				
	Low <16.5253 μg/m^3		High ≥16.5253 μg/m^3		
	Count (N=39)	Percent[A]	Count (N=40)	Percent[A]	p-value
How frequently do you keep the windows open?					0.225
Never or Rarely	15	38%	10	25%	
Sometimes, Frequently, or As Much As Possible	24	62%	29	73%	
How frequently do you clean your entire home?					0.032
1 or Fewer Times per Week	34	87%	26	65%	
2-7 Times per Week	5	13%	13	33%	
How frequently are wet methods used to clean your home?					0.105
1 or Fewer Times per Week	27	69%	20	50%	
2-7 Times per Week	12	31%	19	48%	
How frequently are dry methods used to clean your home?					0.645
1 or Fewer Times per Week	24	62%	22	55%	
2-7 Times per Week	15	38%	17	43%	

A. Numbers may not add to 100% due to rounding or missing data.

B. Fisher's Exact p-value.

Table 37. Cleaning Behavior by Fly Ash Exposure for Aim 1

	Fly Ash (N=79)				
	Absent		Present		
	Count (N=50)	Percent[A]	Count (N=29)	Percent[A]	p-value
How frequently do you keep the windows open?					0.174
Never or Rarely	13	26%	12	41%	
Sometimes, Frequently, or As Much As Possible	36	72%	17	59%	
How frequently do you clean your entire home?					0.700
1 or Fewer Times per Week	37	74%	23	79%	
2-7 Times per Week	12	24%	6	21%	
How frequently are wet methods used to clean your home?					0.801
1 or Fewer Times per Week	29	58%	18	62%	
2-7 Times per Week	20	40%	11	38%	
How frequently are dry methods used to clean your home?					0.669
1 or Fewer Times per Week	28	56%	18	62%	
2-7 Times per Week	21	42%	11	38%	

A. Numbers may not add to 100% due to rounding or missing data.

B. Fisher's Exact p-value.

Table 38. Cleaning Behaviors by Arsenic Exposure for Aim 2

	Filter Arsenic (N=79)				
	Absent		Present		
	Count (N=43)	Percent[A]	Count (N=36)	Percent[A]	p-value
How frequently do you keep the windows open?					0.793
Never or Rarely	14	33%	11	31%	
Sometimes, Frequently, or As Much As Possible	28	65%	25	69%	
How frequently do you clean your entire home?					0.362
1 or Fewer Times per Week	34	79%	26	72%	
2-7 Times per Week	8	19%	10	28%	
How frequently are wet methods used to clean your home?					0.748
1 or Fewer Times per Week	26	60%	21	58%	
2-7 Times per Week	16	37%	14	42%	
How frequently are dry methods used to clean your home?					0.303
1 or Fewer Times per Week	27	63%	19	53%	
2-7 Times per Week	15	35%	16	47%	

A. Numbers may not add to 100% due to rounding or missing data.

B. Fisher's Exact p-value.

Table 39. Cleaning Behaviors by Chromium Exposure for Aim 2

	Filter Chromium (N=79)				
	Absent		Present		
	Count (N=66)	Percent[A]	Count (N=13)	Percent[A]	p-value
How frequently do you keep the windows open?					1.000[B]
Never or Rarely	21	32%	4	31%	
Sometimes, Frequently, or As Much As Possible	44	67%	9	69%	
How frequently do you clean your entire home?					1.000[B]
1 or Fewer Times per Week	51	77%	9	69%	
2-7 Times per Week	15	23%	3	23%	
How frequently are wet methods used to clean your home?					0.882
1 or Fewer Times per Week	40	61%	7	54%	
2-7 Times per Week	26	39%	5	38%	
How frequently are dry methods used to clean your home?					0.961
1 or Fewer Times per Week	39	59%	7	54%	
2-7 Times per Week	27	41%	5	38%	

A. Numbers may not add to 100% due to rounding or missing data.

B. Fisher's Exact p-value.

Table 40. Cleaning Behaviors by Manganese Exposure for Aim 2

	Filter Manganese (N=79)				
	Absent		Present		
	Count (N=45)	Percent[A]	Count (N=34)	Percent[A]	p-value
How frequently do you keep the windows open?					0.206
Never or Rarely	17	38%	8	24%	
Sometimes, Frequently, or As Much As Possible	28	62%	25	74%	
How frequently do you clean your entire home?					0.195
1 or Fewer Times per Week	37	82%	23	68%	
2-7 Times per Week	8	18%	10	29%	
How frequently are wet methods used to clean your home?					0.377
1 or Fewer Times per Week	29	64%	18	53%	
2-7 Times per Week	16	36%	15	44%	
How frequently are dry methods used to clean your home?					0.830
1 or Fewer Times per Week	27	60%	19	56%	
2-7 Times per Week	18	40%	14	41%	

A. Numbers may not add to 100% due to rounding or missing data.

B. Fisher's Exact p-value.

Table 41. Cleaning Behaviors by Nickel Exposure for Aim 2

	Filter Nickel (N=79)				
	Absent		Present		
	Count (N=40)	Percent[A]	Count (N=39)	Percent[A]	p-value
How frequently do you keep the windows open?					0.690
Never or Rarely	12	30%	13	33%	
Sometimes, Frequently, or As Much As Possible	28	70%	25	64%	
How frequently do you clean your entire home?					0.508
1 or Fewer Times per Week	32	80%	28	72%	
2-7 Times per Week	8	20%	10	26%	
How frequently are wet methods used to clean your home?					0.071
1 or Fewer Times per Week	28	70%	19	49%	
2-7 Times per Week	12	30%	19	49%	
How frequently are dry methods used to clean your home?					0.267
1 or Fewer Times per Week	26	65%	20	51%	
2-7 Times per Week	14	35%	18	46%	

A. Numbers may not add to 100% due to rounding or missing data.

B. Fisher's Exact p-value.

Table 42. Cleaning Behaviors by Aluminum Exposure for Aim 2

	Filter Aluminum Levels (N=79)				
	Low ≤0.0566 µg/m^3		High >0.0566 µg/m^3		
	Count (N=40)	Percent[A]	Count (N=39)	Percent[A]	p-value
How frequently do you keep the windows open?					0.012
Never or Rarely	18	45%	7	18%	
Sometimes, Frequently, or As Much As Possible	22	55%	31	79%	
How frequently do you clean your entire home?					0.023
1 or Fewer Times per Week	35	88%	25	64%	
2-7 Times per Week	5	13%	13	33%	
How frequently are wet methods used to clean your home?					0.380
1 or Fewer Times per Week	26	65%	21	54%	
2-7 Times per Week	14	35%	17	44%	
How frequently are dry methods used to clean your home?					0.850
1 or Fewer Times per Week	24	60%	22	56%	
2-7 Times per Week	16	40%	16	41%	

A. Numbers may not add to 100% due to rounding or missing data.
B. Fisher's Exact p-value.

Table 43. Cleaning Behaviors by Copper Exposure for Aim 2

	Filter Copper Levels (N=79)				
	Low ≤ 0.0021 µg/m^3		High >0.0021 µg/m^3		
	Count (N=40)	Percent[A]	Count (N=39)	Percent[A]	p-value
How frequently do you keep the windows open?					0.931
Never or Rarely	13	33%	12	31%	
Sometimes, Frequently, or As Much As Possible	27	68%	26	67%	
How frequently do you clean your entire home?					0.901
1 or Fewer Times per Week	31	78%	29	74%	
2-7 Times per Week	9	23%	9	23%	
How frequently are wet methods used to clean your home?					0.151
1 or Fewer Times per Week	21	53%	26	67%	
2-7 Times per Week	19	48%	12	31%	
How frequently are dry methods used to clean your home?					0.233
1 or Fewer Times per Week	21	53%	25	64%	
2-7 Times per Week	19	48%	13	33%	

A. Numbers may not add to 100% due to rounding or missing data.
B. Fisher's Exact p-value.

Table 44. Cleaning Behaviors by Iron Exposure for Aim 2

	Filter Iron Levels (N=79)				
	Low $\leq$0.0548 µg/m^3		High >0.0548 µg/m^3		
	Count (N=40)	Percent[A]	Count (N=39)	Percent[A]	p-value
How frequently do you keep the windows open?					0.290
Never or Rarely	15	38%	10	26%	
Sometimes, Frequently, or As Much As Possible	25	63%	28	72%	
How frequently do you clean your entire home?					0.023
1 or Fewer Times per Week	35	88%	25	64%	
2-7 Times per Week	5	13%	13	33%	
How frequently are wet methods used to clean your home?					0.180
1 or Fewer Times per Week	27	68%	20	51%	
2-7 Times per Week	13	33%	18	46%	
How frequently are dry methods used to clean your home?					0.516
1 or Fewer Times per Week	25	63%	21	54%	
2-7 Times per Week	15	38%	17	44%	

A. Numbers may not add to 100% due to rounding or missing data.

B. Fisher's Exact p-value.

Table 45. Cleaning Behaviors by Titanium Exposure for Aim 2

	Filter Titanium Levels (N=79)				
	Low ≤ 0.0046 µg/m^3		High >0.0046 µg/m^3		
	Count (N=40)	Percent[A]	Count (N=39)	Percent[A]	p-value
How frequently do you keep the windows open?					0.290
Never or Rarely	15	38%	10	26%	
Sometimes, Frequently, or As Much As Possible	25	63%	28	72%	
How frequently do you clean your entire home?					0.230
1 or Fewer Times per Week	33	83%	27	69%	
2-7 Times per Week	7	18%	11	28%	
How frequently are wet methods used to clean your home?					0.678
1 or Fewer Times per Week	25	63%	22	56%	
2-7 Times per Week	15	38%	16	41%	
How frequently are dry methods used to clean your home?					0.464
1 or Fewer Times per Week	22	55%	24	62%	
2-7 Times per Week	18	45%	14	36%	

A. Numbers may not add to 100% due to rounding or missing data.

B. Fisher's Exact p-value.

Table 46. Cleaning Behaviors by Zinc Exposure for Aim 2

	Filter Zinc Levels (N=79)				
	Low ≤0.0092 μg/m³		High >0.0092 μg/m³		
	Count (N=41)	Percent[A]	Count (N=38)	Percent[A]	p-value
How frequently do you keep the windows open?					0.366
Never or Rarely	15	37%	10	26%	
Sometimes, Frequently, or As Much As Possible	26	63%	27	71%	
How frequently do you clean your entire home?					0.063
1 or Fewer Times per Week	35	85%	25	66%	
2-7 Times per Week	6	15%	12	32%	
How frequently are wet methods used to clean your home?					0.430
1 or Fewer Times per Week	23	56%	24	63%	
2-7 Times per Week	18	44%	13	34%	
How frequently are dry methods used to clean your home?					0.587
1 or Fewer Times per Week	23	56%	23	61%	
2-7 Times per Week	18	44%	14	37%	

A. Numbers may not add to 100% due to rounding or missing data.

B. Fisher's Exact p-value.

Table 47. Unadjusted Modeling of Withdrawn/Depressed Problems for Aims 1 and 2

Model	Exposure vs Reference	OR	95% CI	p-value
PM_{10}	High vs Low	0.653	0.188 - 2.265	0.502
Fly Ash	Present vs Absent	1.280	0.366 - 4.474	0.699
Arsenic	Present vs Absent	1.233	0.361 - 4.219	0.738
Chromium	Present vs Absent	<0.001	<0.001 - >999.999	0.967
Manganese	Present vs Absent	0.387	0.096 - 1.557	0.182
Nickel	Present vs Absent	0.287	0.071 - 1.155	0.079
Aluminum	High vs Low	0.693	0.200 - 2.404	0.564
Copper	High vs Low	2.323	0.638 - 8.461	0.201
Iron	High vs Low	1.030	0.302 3.520	0.962
Titanium	High vs Low	0.457	0.126 - 1.665	0.235
Zinc	High vs Low	1.094	0.320 - 3.738	0.886

Table 48. Unadjusted Modeling of Anxious/Depressed Problems for Aims 1 and 2

Model	Exposure vs Reference	OR	95% CI	p-value
PM_{10}	High vs Low	1.597	0.509 - 5.009	0.423
Fly Ash	Present vs Absent	0.833	0.254 - 2.731	0.763
Arsenic	Present vs Absent	0.756	0.241 - 2.371	0.631
Chromium	Present vs Absent	0.741	0.146 - 3.762	0.718
Manganese	Present vs Absent	0.604	0.185 - 1.966	0.402
Nickel	Present vs Absent	1.700	0.542 - 5.334	0.363
Aluminum	High vs Low	1.217	0.394 - 3.753	0.733
Copper	High vs Low	3.536	1.017 - 12.296	0.047
Iron	High vs Low	1.700	0.542 - 5.334	0.363
Titanium	High vs Low	0.875	0.284 - 2.699	0.816
Zinc	High vs Low	1.810	0.577 5.685	0.309

Table 49. Anxiety Problems Simple Regression Analyses for Aims 1 and 2

Variable	OR	95% CI	p-value
Age	1.067	0.835 - 1.364	0.602
Age_cat (1 vs 0)	1.889	0.305 - 11.684	0.494
Age_cat (2 vs 0)	1.919	0.358 - 10.289	0.447
Sex (F vs M)	0.625	0.185 - 2.111	0.449
Race (1 vs 0)	>999.999	<0.001 - >999.999	0.961
SES_cat (0 vs 2)	1.597	0.342 - 7.461	0.552
SES_cat (1 vs 2)	2.018	0.426 - 9.553	0.376
Married (No vs Yes)	1.971	0.588 - 6.613	0.272
Mom Depression (Yes vs No)	3.318	0.895 - 12.297	0.073
Mom Anxiety (Yes vs No)	1.461	0.381 - 5.599	0.581
Freq of Smoking in the Home (Rarely-Frequently vs Never)	0.519	0.060 - 4.487	0.551
Freq of Cleaning Home (2 or more vs 1 or fewer times per week)	1.619	0.433 6.048	0.474
Windows Open (Sometimes or More vs Never or Rarely)	0.482	0.143 - 1.623	0.239

Table 50. Withdrawn/Depressed Simple Regression Analyses for Aims 1 and 2

Variable	OR	95% CI	p-value
Age	1.214	0.922 - 1.599	0.167
Age_cat (1 vs 0)	2.842	0.270 - 29.896	0.384
Age_cat (2 vs 0)	4.800	0.554 - 41.597	0.155
Sex (F vs M)	1.094	0.320 - 3.738	0.886
Race (1 vs 0)	>999.999	<0.001 - >999.999	0.961
SES_cat (0 vs 2)	1.144	0.356 - 5.781	0.612
SES_cat (1 vs 2)	0.500	0.083 - 3.017	0.450
Married (No vs Yes)	1.565	0.445 - 5.508	0.485
Mom Depression (Yes vs No)	3.318	0.895 - 12.297	0.073
Mom Anxiety (Yes vs No)	0.489	0.097 - 2.472	0.387
Freq of Smoking in the Home (Rarely-Frequently vs Never)	1.451	0.268 - 7.849	0.666
Freq of Cleaning Home (2 or more vs 1 or fewer times per week)	0.625	0.124 - 3.156	0.570
Windows Open (Sometimes or More vs Never or Rarely)	0.268	0.075 - 0.953	0.042

Table 51. Anxious/Depressed Simple Regression Analyses for Aims 1 and 2

Variable	OR	95% CI	p-value
Age	1.142	0.898 - 1.451	0.278
Age_cat (1 vs 0)	2.500	0.425 - 14.710	0.311
Age_cat (2 vs 0)	2.267	0.431 - 11.918	0.334
Sex (F vs M)	0.931	0.302 - 2.874	0.902
Race (1 vs 0)	>999.999	<0.001 - >999.999	0.958
SES_cat (0 vs 2)	1.750	0.448 - 6.840	0.421
SES_cat (1 vs 2)	1.100	0.242 - 4.991	0.902
Married (No vs Yes)	1.024	0.310 - 3.378	0.969
Mom Depression (Yes vs No)	3.354	0.981 - 11.474	0.054
Mom Anxiety (Yes vs No)	1.654	0.475 - 5.768	0.430
Freq of Smoking in the Home (Rarely-Frequently vs Never)	<0.001	<0.001 - >999.999	0.968
Freq of Cleaning Home (2 or more vs 1 or fewer times per week)	0.800	0.199 - 3.217	0.753
Windows Open (Sometimes or More vs Never or Rarely)	0.457	0.144 - 1.447	0.183

Table 52. Variables in the PM_{10} Propensity Score Model for Aim 1

Variable	Parameter Estimate	SE	OR	95% CI	p-value
Age	0.017	0.119	1.017	0.805 - 1.284	0.889
Sex (F vs M)	0.432	0.595	1.541	0.480 - 4.949	0.468
Race (White vs Non-White)	-0.987	0.723	0.373	0.090 - 1.539	0.173
SES (0 vs 2)	0.679	0.690	1.973	0.510 - 7.630	0.325
SES (1 vs 2)	0.872	0.744	2.392	0.557 - 10.278	0.241
Married (No vs Yes)	1.170	0.689	3.222	0.835 - 12.443	0.090
Mom Depression (Yes vs No)	0.722	0.647	2.059	0.579 - 7.322	0.265
Freq of Smoking in the Home (Rarely-Frequently vs Never)	1.486	0.999	4.418	0.624 - 31.268	0.137
Freq of Cleaning Home (2 or more vs 1 or fewer times per week)	0.596	0.811	1.814	0.370 - 8.889	0.463

Table 53. Variables in the Fly Ash Propensity Score Model for Aim 1

Variable	Parameter Estimate	SE	OR	95% CI	p-value
Age	0.148	0.112	1.159	0.930 - 1.445	0.188
Sex (F vs M)	0.606	0.555	1.833	0.618 - 5.436	0.274
Race (White vs Non-White)	-0.241	0.666	0.786	0.213 - 2.900	0.717
SES (0 vs 2)	-0.350	0.645	0.705	0.199 - 2.492	0.587
SES (1 vs 2)	0.197	0.704	1.218	0.306 - 4.842	0.780
Married (No vs Yes)	0.235	0.639	1.265	0.362 - 4.423	0.713
Mom Depression (Yes vs No)	0.796	0.612	2.217	0.668 - 7.359	0.193
Freq of Smoking in the Home (Rarely-Frequently vs Never)	-0.003	0.846	0.997	0.190 5.236	0.997
Freq of Cleaning Home (2 or more vs 1 or fewer times per week)	-0.416	0.747	0.660	0.153 2.852	0.578

Table 54. Variables in the Metal Score Propensity Model for Aim 2

Variable	Parameter Estimate	SE	OR	95% CI	p-value
Age	-0.028	0.112	0.972	0.780 - 1.212	0.802
Sex (F vs M)	0.668	0.557	1.950	0.655 - 5.806	0.230
Race (White vs Non-White)	0.895	0.695	2.448	0.627 - 9.551	0.197
SES (0 vs 2)	1.481	0.674	4.399	1.174 - 16.486	0.028
SES (1 vs 2)	1.302	0.729	3.677	0.882 - 15.336	0.074
Married (No vs Yes)	0.501	0.654	1.651	0.459 - 5.942	0.443
Mom Depression (Yes vs No)	0.284	0.625	1.328	0.390 - 4.524	0.650
Freq of Smoking in the Home (Rarely-Frequently vs Never)	-0.700	0.888	0.496	0.087 - 2.830	0.430
Freq of Cleaning Home (2 or more vs 1 or fewer times per week)	0.740	0.782	2.095	0.452 - 9.707	0.344

Table 55. Demographics by Withdrawn/Depressed Problems for Aim 3

	Withdrawn/Depressed Problems (N=69)				
	t-score <65		t-score ≥ 65		
	Count (N=60)	Percent[A]	Count (N=9)	Percent[A]	p-value
Sex					0.734[B]
Male	29	48%	5	56%	
Female	31	52%	4	44%	
Age					0.591[B]
6-8 years	16	27%	1	11%	
9-11 years	17	28%	2	22%	
12-14 years	27	45%	6	67%	
Race					0.293[B]
White	45	75%	9	100%	
African American	14	23%	0	0%	
Asian	1	2%	0	0%	
SES					0.402[B]
Low	20	33%	4	44%	
Middle	20	33%	1	11%	
High	20	33%	4	44%	
Parents' Marriage Status					0.699[B]
Married	44	73%	3	33%	
Unmarried	16	27%	6	67%	
Smoking in the Home					0.645[B]
No	49	82%	7	78%	
Yes	10	17%	2	22%	
Freq of Smoking in Home					0.611[B]
None	51	85%	7	78%	
Rarely-Frequently	8	13%	2	22%	
Mom Anxiety					1.000[B]
No	41	68%	7	78%	
Yes	18	30%	2	22%	
Mom Depression					0.212[B]
No	46	77%	5	56%	
Yes	13	22%	4	44%	

A. Numbers may not add to 100% due to rounding or missing data.

B. Fisher's Exact p-value.

Table 56. Demographics by Anxious/Depressed Problems for Aim 3

	Anxious/Depressed Problems				
	t-score <65		t-score ≥ 65		
	Count (N=59)	Percent[A]	Count (N=10)	Percent[A]	p-value
Sex					0.513[B]
Male	28	47%	6	60%	
Female	31	53%	4	40%	
Age					0.608[B]
6-8 years	16	27%	1	10%	
9-11 years	16	27%	3	30%	
12-14 years	27	46%	6	60%	
Race					0.237[B]
White	44	75%	10	100%	
African American	14	24%	0	0%	
Asian	1	2%	0	0%	
SES					0.266[B]
Low	18	31%	6	60%	
Middle	19	32%	2	20%	
High	22	37%	2	20%	
Parents' Marriage Status					0.715[B]
Married	42	71%	8	80%	
Unmarried	17	29%	2	20%	
Smoking in the Home					0.492
No	47	80%	9	90%	
Yes	11	19%	7	70%	
Freq of Smoking in Home					0.337[B]
None	48	81%	10	100%	
Rarely-Frequently	10	17%	0	0%	
Mom Anxiety					0.122
No	43	73%	5	50%	
Yes	15	25%	5	50%	
Mom Depression					0.048
No	46	78%	5	50%	
Yes	12	20%	5	50%	

A. Numbers may not add to 100% due to rounding or missing data.

B. Fisher's Exact p-value.

Table 57. Demographics by Arsenic Exposure for Aim 3

	Nail Arsenic (N=69)				
	Absent		Present		
	Count (N=65)	Percent[A]	Count (N=3)	Percent[A]	p-value
Sex					1.000[B]
Male	33	51%	1	33%	
Female	33	51%	2	67%	
Age					1.000[B]
6-8 years	16	25%	1	33%	
9-11 years	18	28%	1	33%	
12-14 years	32	49%	1	33%	
Race					0.527[B]
White	52	80%	2	67%	
African American	13	20%	1	33%	
Asian	1	2%	0	0%	
SES					1.000[B]
Low	23	35%	1	33%	
Middle	20	31%	1	33%	
High	23	35%	1	33%	
Parents' Marriage Status					1.000[B]
Married	48	74%	2	67%	
Unmarried	18	28%	1	33%	
Smoking in the Home					1.000[B]
No	53	82%	3	100%	
Yes	12	18%	0	0%	
Freq of Smoking in Home					0.384[B]
None	56	86%	2	67%	
Rarely-Frequently	9	14%	1	33%	

A. Numbers may not add to 100% due to rounding or missing data.

B. Fisher's Exact p-value.

Table 58. Demographics by Manganese Exposure for Aim 3

	Nail Manganese (N=69)				
	Absent		Present		
	Count (N=55)	Percent[A]	Count (N=14)	Percent[A]	p-value
Sex					0.133[B]
Male	30	55%	10	71%	
Female	25	45%	4	29%	
Age					0.055[B]
6-8 years	10	18%	7	50%	
9-11 years	16	29%	3	21%	
12-14 years	29	53%	4	29%	
Race					0.573[B]
White	44	80%	10	71%	
African American	10	18%	4	29%	
Asian	1	2%	0	0%	
SES					0.216[B]
Low	18	33%	6	43%	
Middle	15	27%	6	43%	
High	22	40%	2	14%	
Parents' Marriage Status					0.508[B]
Married	41	75%	9	64%	
Unmarried	14	25%	5	36%	
Smoking in the Home					0.701[B]
No	45	82%	11	79%	
Yes	9	16%	3	21%	
Freq of Smoking in Home					0.674[B]
None	45	82%	13	93%	
Rarely-Frequently	9	16%	1	7%	

A. Numbers may not add to 100% due to rounding or missing data.

B. Fisher's Exact p-value.

Table 59. Demographics by Titanium Exposure for Aim 3

	Nail Titanium (N=69)				
	Absent		Present		
	Count (N=35)	Percent[A]	Count (N=34)	Percent[A]	p-value
Sex					0.022
Male	22	63%	22	65%	
Female	13	37%	12	35%	
Age					0.010
6-8 years	5	14%	12	35%	
9-11 years	7	20%	12	35%	
12-14 years	23	66%	10	29%	
Race					0.662[B]
White	26	74%	28	82%	
African American	8	23%	6	18%	
Asian	1	3%	0	0%	
SES					0.833
Low	11	31%	13	38%	
Middle	11	31%	10	29%	
High	13	37%	11	32%	
Parents' Marriage Status					0.155
Married	28	80%	22	65%	
Unmarried	7	20%	12	35%	
Smoking in the Home					
No	28	80%	28	82%	1.000
Yes	6	17%	6	18%	
Freq of Smoking in Home					0.734[B]
None	28	80%	30	88%	
Rarely-Frequently	6	17%	4	12%	

A. Numbers may not add to 100% due to rounding or missing data.

B. Fisher's Exact p-value.

Table 60. Demographics by Aluminum Exposure for Aim 3

	Nail Aluminum Levels (N=69)				
	Low ≤130 ppm		High >130 ppm		
	Count (N=35)	Percent[A]	Count (N=34)	Percent[A]	p-value
Sex					0.717
Male	18	51%	16	47%	
Female	17	49%	18	53%	
Age					0.516
6-8 years	7	20%	10	29%	
9-11 years	8	23%	10	29%	
12-14 years	19	54%	14	41%	
Race					0.371[B]
White	26	74%	28	82%	
African American	9	26%	5	15%	
Asian	0	0%	1	3%	
SES					0.905
Low	13	37%	11	32%	
Middle	10	29%	11	32%	
High	12	34%	12	35%	
Parents' Marriage Status					0.463
Married	24	69%	26	76%	
Unmarried	11	31%	8	24%	
Smoking in the Home					0.525
No	27	77%	29	85%	
Yes	7	20%	5	15%	
Freq of Smoking in Home					0.305[B]
None	27	77%	31	91%	
Rarely-Frequently	7	20%	3	9%	

A. Numbers may not add to 100% due to rounding or missing data.

B. Fisher's Exact p-value.

Table 61. Demographics by Chromium Exposure for Aim 3

	Nail Chromium Levels (N=69)				
	Low ≤5.6 ppm		High >5.6 ppm		
	Count (N=35)	Percent[A]	Count (N=34)	Percent[A]	p-value
Sex					0.906
Male	17	49%	17	50%	
Female	18	51%	17	50%	
Age					0.112
6-8 years	6	17%	11	32%	
9-11 years	8	23%	11	32%	
12-14 years	21	60%	12	35%	
Race					0.053[B]
White	31	89%	23	68%	
African American	4	11%	10	29%	
Asian	0	0%	1	3%	
SES					0.262
Low	15	43%	9	26%	
Middle	8	23%	13	38%	
High	12	34%	12	35%	
Parents' Marriage Status					0.070
Married	22	63%	28	82%	
Unmarried	13	37%	6	18%	
Smoking in the Home					0.911
No	29	83%	27	79%	
Yes	6	17%	6	18%	
Freq of Smoking in Home					0.735[B]
None	29	83%	29	85%	
Rarely-Frequently	6	17%	4	12%	

A. Numbers may not add to 100% due to rounding or missing data.

B. Fisher's Exact p-value.

Table 62. Demographics by Copper Exposure for Aim 3

	Nail Copper Levels (N=69)				
	Low ≤4.2 ppm		High >4.2 ppm		
	Count (N=36)	Percent[A]	Count (N=33)	Percent[A]	p-value
Sex					0.543
Male	19	53%	15	45%	
Female	17	47%	18	55%	
Age					0.231
6-8 years	6	17%	11	33%	
9-11 years	12	33%	7	21%	
12-14 years	18	50%	15	45%	
Race					0.104[B]
White	25	69%	29	88%	
African American	10	28%	4	12%	
Asian	1	3%	0	0%	
SES					0.541
Low	12	33%	12	36%	
Middle	13	36%	8	24%	
High	11	31%	13	39%	
Parents' Marriage Status					0.260
Married	24	67%	26	79%	
Unmarried	12	33%	7	21%	
Smoking in the Home					0.111[B]
No	26	72%	30	91%	
Yes	9	25%	3	9%	
Freq of Smoking in Home					0.085[B]
None	27	75%	31	94%	
Rarely-Frequently	8	22%	2	6%	

A. Numbers may not add to 100% due to rounding or missing data.

B. Fisher's Exact p-value.

Table 63. Demographics by Iron Exposure for Aim 3

	Nail Iron Levels (N=69)				
	Low ≤72 ppm		High >72 ppm		
	Count (N=35)	Percent[A]	Count (N=34)	Percent[A]	p-value
Sex					0.717
Male	18	51%	16	47%	
Female	17	49%	18	53%	
Age					0.111
6-8 years	5	14%	12	35%	
9-11 years	10	29%	9	26%	
12-14 years	20	57%	13	38%	
Race					0.881[B]
White	28	80%	26	76%	
African American	7	20%	7	21%	
Asian	0	0%	1	3%	
SES					0.262
Low	15	43%	9	26%	
Middle	8	23%	13	38%	
High	12	34%	12	35%	
Parents' Marriage Status					0.203
Married	23	66%	27	79%	
Unmarried	12	34%	7	21%	
Smoking in the Home					0.341[B]
No	26	74%	30	88%	
Yes	8	23%	4	12%	
Freq of Smoking in Home					0.013[B]
None	25	71%	33	97%	
Rarely-Frequently	9	26%	1	3%	

A. Numbers may not add to 100% due to rounding or missing data.

B. Fisher's Exact p-value.

Table 64. Demographics by Nickel Exposure for Aim 3

	Nail Nickel Levels (N=69)				
	Low ≤1.5 ppm		High >1.5 ppm		
	Count (N=35)	Percent[A]	Count (N=34)	Percent[A]	p-value
Sex					0.398
Male	19	54%	15	44%	
Female	16	46%	19	56%	
Age					0.184
6-8 years	8	23%	9	26%	
9-11 years	13	37%	6	18%	
12-14 years	14	40%	19	56%	
Race					0.053[B]
White	31	89%	23	68%	
African American	4	11%	10	29%	
Asian	0	0%	1	3%	
SES					0.219
Low	9	26%	15	44%	
Middle	11	31%	10	29%	
High	15	43%	9	26%	
Parents' Marriage Status					0.155
Married	28	80%	22	65%	
Unmarried	7	20%	12	35%	
Smoking in the Home					0.111[B]
No	26	74%	30	88%	
Yes	9	26%	3	9%	
Freq of Smoking in Home					0.085[B]
None	27	77%	31	91%	
Rarely-Frequently	8	23%	2	6%	

A. Numbers may not add to 100% due to rounding or missing data.

B. Fisher's Exact p-value.

Table 65. Demographics by Zinc Exposure for Aim 3

	Nail Zinc Levels (N=69)				
	Low ≤83 ppm		High >83 ppm		
	Count (N=36)	Percent[A]	Count (N=33)	Percent[A]	p-value
Sex					0.011
Male	23	64%	11	33%	
Female	13	36%	22	67%	
Age					0.015[B]
6-8 years	4	11%	13	39%	
9-11 years	10	28%	9	27%	
12-14 years	22	61%	11	33%	
Race					0.878[B]
White	27	75%	27	82%	
African American	8	22%	6	18%	
Asian	1	3%	0	0%	
SES					0.352
Low	10	28%	14	42%	
Middle	11	31%	10	30%	
High	15	42%	9	27%	
Parents' Marriage Status					0.622
Married	37	103%	23	70%	
Unmarried	9	25%	10	30%	
Smoking in the Home					0.454
No	30	83%	26	79%	
Yes	5	14%	7	21%	
Freq of Smoking in Home					0.920
None	30	83%	38	115%	
Rarely-Frequently	5	14%	5	15%	

A. Numbers may not add to 100% due to rounding or missing data.

B. Fisher's Exact p-value.

Table 66. Contingency Table of Outcomes for Aim 3

		AD = 0	AD = 1	Total
A = 0	W/D = 0	55	1	56
	W/D = 1	2	1	3
A = 1	W/D = 0	1	3	4
	W/D = 1	1	5	6
	Total	59	10	69

Table 67. Cleaning Behaviors by Anxiety Problems for Aim 3

	Anxiety Problems (N=69)				
	t-score <65		t-score ≥ 65		
	Count (N=59)	Percent[A]	Count (N=10)	Percent[A]	p-value
How frequently do you keep the windows open?					1.000[B]
Never or Rarely	17	29%	3	30%	
Sometimes, Frequently, or As Much As Possible	41	69%	7	70%	
How frequently do you clean your entire home?					1.000[B]
1 or Fewer Times per Week	46	78%	8	80%	
2-7 Times per Week	13	22%	2	20%	
How frequently are wet methods used to clean your home?					0.729[B]
1 or Fewer Times per Week	35	59%	7	70%	
2-7 Times per Week	24	41%	3	30%	
How frequently are dry methods used to clean your home?					0.729[B]
1 or Fewer Times per Week	34	58%	7	70%	
2-7 Times per Week	25	42%	3	30%	

A. Numbers may not add to 100% due to rounding or missing data.
B. Fisher's Exact p-value.

Table 68. Cleaning Behaviors by Withdrawn/Depressed Problems for Aim 3

	Withdrawn/Depressed Problems (N=69)				
	t-score <65		t-score ≥ 65		
	Count (N=60)	Percent[A]	Count (N=9)	Percent[A]	p-value
How frequently do you keep the windows open?					0.432[B]
Never or Rarely	16	27%	4	44%	
Sometimes, Frequently, or As Much As Possible	43	72%	5	56%	
How frequently do you clean your entire home?					0.672[B]
1 or Fewer Times per Week	46	77%	8	89%	
2-7 Times per Week	14	23%	1	11%	
How frequently are wet methods used to clean your home?					0.079[B]
1 or Fewer Times per Week	34	57%	8	89%	
2-7 Times per Week	26	43%	1	11%	
How frequently are dry methods used to clean your home?					0.073[B]
1 or Fewer Times per Week	33	55%	8	89%	
2-7 Times per Week	27	45%	1	11%	

A. Numbers may not add to 100% due to rounding or missing data.

B. Fisher's Exact p-value.

Table 69. Cleaning Behaviors by Anxious/Depressed Problems for Aim 3

	Anxious/Depressed Problems				
	t-score <65		t-score ≥ 65		
	Count (N=59)	Percent[A]	Count (N=10)	Percent[A]	p-value
How frequently do you keep the windows open?					0.465[B]
Never or Rarely	16	27%	4	40%	
Sometimes, Frequently, or As Much As Possible	42	71%	6	60%	
How frequently do you clean your entire home?					0.442[B]
1 or Fewer Times per Week	45	76%	9	90%	
2-7 Times per Week	14	24%	1	10%	
How frequently are wet methods used to clean your home?					0.295[B]
1 or Fewer Times per Week	34	58%	8	80%	
2-7 Times per Week	25	42%	2	20%	
How frequently are dry methods used to clean your home?					0.184[B]
1 or Fewer Times per Week	33	56%	8	80%	
2-7 Times per Week	26	44%	2	20%	

A. Numbers may not add to 100% due to rounding or missing data.
B. Fisher's Exact p-value.

Table 70. Cleaning Behaviors by Arsenic Exposure for Aim 3

	Nail Arsenic (N=69)				
	Absent		Present		
	Count (N=65)	Percent[A]	Count (N=3)	Percent[A]	p-value
How frequently do you keep the windows open?					1.000[B]
Never or Rarely	19	29%	1	33%	
Sometimes, Frequently, or As Much As Possible	46	71%	2	67%	
How frequently do you clean your entire home?					0.527[B]
1 or Fewer Times per Week	52	80%	2	67%	
2-7 Times per Week	14	22%	1	33%	
How frequently are wet methods used to clean your home?					1.000[B]
1 or Fewer Times per Week	40	62%	2	67%	
2-7 Times per Week	26	40%	1	33%	
How frequently are dry methods used to clean your home?					0.266[B]
1 or Fewer Times per Week	38	58%	3	100%	
2-7 Times per Week	28	43%	6	200%	

A. Numbers may not add to 100% due to rounding or missing data.

B. Fisher's Exact p-value.

Table 71. Cleaning Behaviors by Manganese Exposure for Aim 3

	Nail Manganese (N=69)				
	Absent		Present		
	Count (N=55)	Percent[A]	Count (N=14)	Percent[A]	p-value
How frequently do you keep the windows open?					0.204[B]
Never or Rarely	18	33%	2	14%	
Sometimes, Frequently, or As Much As Possible	36	65%	12	86%	
How frequently do you clean your entire home?					0.156
1 or Fewer Times per Week	45	82%	9	64%	
2-7 Times per Week	10	18%	5	36%	
How frequently are wet methods used to clean your home?					0.769
1 or Fewer Times per Week	33	60%	9	64%	
2-7 Times per Week	22	40%	5	36%	
How frequently are dry methods used to clean your home?					0.678
1 or Fewer Times per Week	32	58%	9	64%	
2-7 Times per Week	23	42%	5	36%	

A. Numbers may not add to 100% due to rounding or missing data.
B. Fisher's Exact p-value.

Table 72. Cleaning Behaviors by Titanium Exposure for Aim 3

	Nail Titanium (N=69)				
	Absent		Present		
	Count (N=35)	Percent[A]	Count (N=34)	Percent[A]	p-value
How frequently do you keep the windows open?					0.110
Never or Rarely	13	37%	7	21%	
Sometimes, Frequently, or As Much As Possible	21	60%	27	79%	
How frequently do you clean your entire home?					0.163
1 or Fewer Times per Week	25	71%	29	85%	
2-7 Times per Week	10	29%	5	15%	
How frequently are wet methods used to clean your home?					0.731
1 or Fewer Times per Week	22	63%	20	59%	
2-7 Times per Week	13	37%	14	41%	
How frequently are dry methods used to clean your home?					0.696
1 or Fewer Times per Week	20	57%	21	62%	
2-7 Times per Week	15	43%	13	38%	

A. Numbers may not add to 100% due to rounding or missing data.

B. Fisher's Exact p-value.

Table 73. Cleaning Behaviors by Aluminum Exposure for Aim 3

	Nail Aluminum Levels (N=69)				
	Low ≤130 ppm		High >130 ppm		
	Count (N=35)	Percent[A]	Count (N=34)	Percent[A]	p-value
How frequently do you keep the windows open?					0.110
Never or Rarely	13	37%	7	21%	
Sometimes, Frequently, or As Much As Possible	21	60%	27	79%	
How frequently do you clean your entire home?					0.128
1 or Fewer Times per Week	30	86%	24	71%	
2-7 Times per Week	5	14%	10	29%	
How frequently are wet methods used to clean your home?					0.184
1 or Fewer Times per Week	24	69%	18	53%	
2-7 Times per Week	11	31%	16	47%	
How frequently are dry methods used to clean your home?					0.555
1 or Fewer Times per Week	22	63%	19	56%	
2-7 Times per Week	13	37%	15	44%	

A. Numbers may not add to 100% due to rounding or missing data.

B. Fisher's Exact p-value.

Table 74. Cleaning Behaviors by Chromium Exposure for Aim 3

	Nail Chromium Levels (N=69)				
	Low ≤5.6 ppm		High >5.6 ppm		
	Count (N=35)	Percent[A]	Count (N=34)	Percent[A]	p-value
How frequently do you keep the windows open?					0.048
Never or Rarely	14	40%	6	18%	
Sometimes, Frequently, or As Much As Possible	21	60%	27	79%	
How frequently do you clean your entire home?					0.348
1 or Fewer Times per Week	29	83%	25	74%	
2-7 Times per Week	6	17%	9	26%	
How frequently are wet methods used to clean your home?					0.731
1 or Fewer Times per Week	22	63%	20	59%	
2-7 Times per Week	13	37%	14	41%	
How frequently are dry methods used to clean your home?					0.280
1 or Fewer Times per Week	23	66%	18	53%	
2-7 Times per Week	12	34%	16	47%	

A. Numbers may not add to 100% due to rounding or missing data.

B. Fisher's Exact p-value.

Table 75. Cleaning Behaviors by Copper Exposure for Aim 3

	Nail Copper Levels (N=69)				
	Low ≤4.2 ppm		High >4.2 ppm		
	Count (N=36)	Percent[A]	Count (N=33)	Percent[A]	p-value
How frequently do you keep the windows open?					0.222
Never or Rarely	8	22%	12	36%	
Sometimes, Frequently, or As Much As Possible	27	75%	21	64%	
How frequently do you clean your entire home?					0.204
1 or Fewer Times per Week	26	72%	28	85%	
2-7 Times per Week	10	28%	5	15%	
How frequently are wet methods used to clean your home?					0.303
1 or Fewer Times per Week	24	67%	18	55%	
2-7 Times per Week	12	33%	15	45%	
How frequently are dry methods used to clean your home?					0.765
1 or Fewer Times per Week	22	61%	19	58%	
2-7 Times per Week	14	39%	14	42%	

A. Numbers may not add to 100% due to rounding or missing data.
B. Fisher's Exact p-value.

Table 76. Cleaning Behaviors by Iron Exposure for Aim 3

	Nail Iron Levels (N=69)				
	Low ≤72 ppm		High >72 ppm		
	Count (N=35)	Percent[A]	Count (N=34)	Percent[A]	p-value
How frequently do you keep the windows open?					1.000
Never or Rarely	10	29%	10	29%	
Sometimes, Frequently, or As Much As Possible	24	69%	24	71%	
How frequently do you clean your entire home?					0.722
1 or Fewer Times per Week	28	80%	26	76%	
2-7 Times per Week	7	20%	8	24%	
How frequently are wet methods used to clean your home?					0.403
1 or Fewer Times per Week	23	66%	19	56%	
2-7 Times per Week	12	34%	15	44%	
How frequently are dry methods used to clean your home?					0.555
1 or Fewer Times per Week	22	63%	19	56%	
2-7 Times per Week	13	37%	15	44%	

A. Numbers may not add to 100% due to rounding or missing data.

B. Fisher's Exact p-value.

Table 77. Cleaning Behaviors by Nickel Exposure for Aim 3

	Nail Nickel Levels (N=69)				
	Low ≤1.5 ppm		High >1.5 ppm		
	Count (N=35)	Percent[A]	Count (N=34)	Percent[A]	p-value
How frequently do you keep the windows open?					0.222
Never or Rarely	8	23%	12	35%	
Sometimes, Frequently, or As Much As Possible	27	77%	21	62%	
How frequently do you clean your entire home?					0.722
1 or Fewer Times per Week	28	80%	26	76%	
2-7 Times per Week	7	20%	8	24%	
How frequently are wet methods used to clean your home?					0.731
1 or Fewer Times per Week	22	63%	20	59%	
2-7 Times per Week	13	37%	14	41%	
How frequently are dry methods used to clean your home?					0.921
1 or Fewer Times per Week	21	60%	20	59%	
2-7 Times per Week	14	40%	14	41%	

A. Numbers may not add to 100% due to rounding or missing data.

B. Fisher's Exact p-value.

Table 78. Cleaning Behaviors by Zinc Exposure for Aim 3

	Nail Zinc Levels (N=69)				
	Low ≤83 ppm		High >83 ppm		
	Count (N=36)	Percent[A]	Count (N=33)	Percent[A]	p-value
How frequently do you keep the windows open?					0.707
Never or Rarely	11	31%	9	27%	
Sometimes, Frequently, or As Much As Possible	24	67%	24	73%	
How frequently do you clean your entire home?					0.286
1 or Fewer Times per Week	30	83%	24	73%	
2-7 Times per Week	6	17%	9	27%	
How frequently are wet methods used to clean your home?					0.044
1 or Fewer Times per Week	26	72%	16	48%	
2-7 Times per Week	10	28%	17	52%	
How frequently are dry methods used to clean your home?					0.200
1 or Fewer Times per Week	24	67%	17	52%	
2-7 Times per Week	12	33%	16	48%	

A. Numbers may not add to 100% due to rounding or missing data.

B. Fisher's Exact p-value.

Table 79. Unadjusted Modeling of Withdrawn/Depressed Problems for Aim 3

Model	Exposure vs Reference	OR	95% CI	p-value
Arsenic	Present vs Absent	3.625	0.294 - 44.684	0.315
Manganese	Present vs Absent	1.143	0.210 - 6.219	0.877
Titanium	Present vs Absent	1.336	0.327 - 5.467	0.687
Aluminum	High vs Low	0.468	0.107 - 2.046	0.313
Chromium	High vs Low	0.250	0.048 - 1.304	0.100
Copper	High vs Low	11.198	1.316 - 95.285	0.027
Iron	High vs Low	0.468	0.107 - 2.046	0.313
Nickel	High vs Low	2.286	0.523 - 9.999	0.272
Zinc	High vs Low	1.107	0.290 - 4.232	0.882

Table 80. Unadjusted Modeling of Anxious/Depressed Problems for Aim 3

Model	Exposure vs Reference	OR	95% CI	p-value
Arsenic	Present vs Absent	<0.001	<0.001 - >999.999	0.977
Manganese	Present vs Absent	3.267	0.777 - 13.738	0.106
Titanium	Present vs Absent	1.661	0.424 - 6.499	0.466
Aluminum	High vs Low	1.034	0.271 - 3.953	0.961
Chromium	High vs Low	0.644	0.165 - 2.522	0.528
Copper	High vs Low	13.121	1.559 - 110.407	0.018
Iron	High vs Low	1.034	0.271 - 3.953	0.961
Nickel	High vs Low	1.661	0.424 - 6.499	0.466
Zinc	High vs Low	1.778	0.454 - 6.961	0.409

Table 81. Anxiety Problems Simple Regression Analyses for Aim 3

Variable	OR	95% CI	p-value
Age	1.196	0.885 - 1.615	0.244
Age_cat (1 vs 0)	3.000	0.281 - 31.992	0.363
Age_cat (2 vs 0)	3.556	0.392 - 32.265	0.260
Sex (F vs M)	0.362	0.085 - 1.536	0.168
Race (1 vs 0)	>999.999	<0.001 - >999.999	0.947
SES_cat (0 vs 2)	1.400	0.278 - 7.055	0.684
SES_cat (1 vs 2)	1.167	0.209 - 6.513	0.861
Married (No vs Yes)	1.956	0.485 - 7.885	0.346
Mom Depression (Yes vs No)	3.833	0.952 - 15.436	0.059
Mom Anxiety (Yes vs No)	1.750	0.436 - 7.026	0.430
Freq of Smoking in the Home (Rarely-Frequently vs Never)	0.605	0.068 - 5.377	0.652
Freq of Cleaning Home (2 or more vs 1 or fewer times per week)	0.885	0.167 - 4.687	0.885
Windows Open (Sometimes or More vs Never or Rarely)	0.967	0.223 - 4.190	0.965

Table 82. Withdrawn/Depressed Problems Simple Regression Analyses for Aim 3

Variable	OR	95% CI	p-value
Age	1.248	0.900 - 1.730	0.185
Age_cat (1 vs 0)	1.882	0.155 - 22.822	0.620
Age_cat (2 vs 0)	3.555	0.392 - 32.250	0.260
Sex (F vs M)	0.748	0.183 - 3.062	0.687
Race (1 vs 0)	>999.999	<0.001 - >999.999	0.950
SES_cat (0 vs 2)	1.000	0.219 - 4.564	1.000
SES_cat (1 vs 2)	0.250	0.026 - 2.438	0.233
Married (No vs Yes)	1.375	0.307 - 6.159	0.677
Mom Depression (Yes vs No)	2.831	0.663 - 12.090	0.160
Mom Anxiety (Yes vs No)	0.651	0.123 - 3.444	0.613
Freq of Smoking in the Home (Rarely-Frequently vs Never)	1.821	0.320 - 10.370	0.499
Freq of Cleaning Home (2 or more vs 1 or fewer times per week)	0.411	0.047 - 3.573	0.420
Windows Open (Sometimes or More vs Never or Rarely)	0.465	0.111 - 1.953	0.296

Table 83. Anxious/Depressed Problems Simple Regression Analyses for Aim 3

Variable	OR	95% CI	p-value
Age	1.256	0.918 - 1.719	0.155
Age_cat (1 vs 0)	3.000	0.281 - 31.992	0.363
Age_cat (2 vs 0)	3.556	0.392 - 32.265	0.260
Sex (F vs M)	0.602	0.154 - 2.357	0.466
Race (1 vs 0)	>999.999	<0.001 - >999.999	0.947
SES_cat (0 vs 2)	3.667	0.658 - 20.420	0.138
SES_cat (1 vs 2)	1.158	0.148 - 9.029	0.889
Married (No vs Yes)	0.618	0.119 - 3.212	0.567
Mom Depression (Yes vs No)	3.833	0.952 - 15.436	0.059
Mom Anxiety (Yes vs No)	2.867	0.727 - 11.302	0.132
Freq of Smoking in the Home (Rarely-Frequently vs Never)	<0.001	<0.001 - >999.999	0.957
Freq of Cleaning Home (2 or more vs 1 or fewer times per week)	0.357	0.042 - 3.070	0.348
Windows Open (Sometimes or More vs Never or Rarely)	0.571	0.142 - 2.294	0.430

Table 84. Variables in the Nail Metal Score Propensity Model for Aim 3

Variable	Parameter Estimate	SE	OR	95% CI	p-value
Age	-0.241	0.149	0.786	0.587 - 1.053	0.107
Sex (F vs M)	0.984	0.675	2.675	0.712 - 10.046	0.145
Race (White vs Non-White)	0.882	0.808	2.416	0.495 - 11.780	0.275
SES (0 vs 2)	0.525	0.764	1.690	0.378 - 7.549	0.492
SES (1 vs 2)	0.701	0.887	2.016	0.354 - 11.476	0.429
Married (No vs Yes)	0.405	0.864	1.499	0.276 - 8.151	0.640
Mom Depression (Yes vs No)	-0.376	0.836	0.687	0.133 - 3.533	0.653
Freq of Smoking in the Home (Rarely-Frequently vs Never)	-1.274	0.938	0.280	0.044 - 1.761	0.175
Freq of Cleaning Home (2 or more vs 1 or fewer times per week)	-0.409	0.814	0.664	0.135 - 3.274	0.615

CURRICULUM VITA

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EDUCATION

PhD, Epidemiology	University of Louisville, Louisville, KY	2013-2017
MPH, Emergency Preparedness	Wright State University, Dayton, OH	2010-2012
BS, Chemistry	Centre College, Danville, KY	2006-2010

RESEARCH EXPERIENCE

University of Louisville Louisville, KY 2015-Present
Coal Ash Project

- Recruited community members from neighborhoods surrounding two coal ash storage facilities.
- Worked with team members to consent participants in their homes.
- Calibrated personal air pumps, assembled air sampling trains, set up air pumps in the participant’s home, and conducted gravimetric analysis on the air filter.
- Collected dust particles using lift tape.
- Collected, cleaned, and prepared nail (fingernail and toenail) samples for PIXE analysis.
- Created and regularly updated a database for the environmental health and home cleaning questionnaire responses.
- Responded to community members’ questions and concerns about participating in the project.
- Worked with various team members, including faculty members from multiple departments, other students, staff, and community leaders to ensure project success.

University of Louisville Louisville, KY 2015
Division of Infectious Diseases - Volunteer

- Reviewed informed consent forms and screening data for quality assurance.
- Entered screening data into RedCap.
- Contacted various public health departments in neighboring states to form collaborations for refugee health research.
- Prepared materials for the Refugee Health Program Immunization Clinic.
- Assisted patients with registration and immunization history forms at the Refugee Health Program Immunization Clinic.
- Conducted literature review searches on infectious diseases such as influenza and pneumonia.
- Reviewed numerous drafts of a grant proposal for a pneumococcal vaccine study.

University of Louisville Louisville, KY 2014-2015
Community-Based Participatory Research Project: Coal Ash Project - Volunteer

- Recruited community members from multiple neighborhoods to participate in the study.
- Worked with community leaders to engage community members participating in the study.
- Designed a comprehensive questionnaire to collect data for a non-exposed adult group complimenting previously collected data on a coal ash exposed adult population.
- Administered questionnaires to adults from non-exposed communities.
- Assisted community members with literacy issues in completing questionnaires.
- Created a database with questionnaire responses.
- Analyzed data from exposed and non-exposed populations to evaluate differences in health outcomes.
- Presented results at the American Public Health Association annual meeting, 2016.

Wright State University Dayton, OH 2011-2012
Master of Public Health – Culminating Experience

- Analyzed Montgomery County birth data from 2000-2010.
- Assessed how maternal factors such as age, education, BMI rates, infertility use, and gestational weight gain changed in Montgomery County and how these compared to overall trends in the United States.
- Assessed how birthing procedures such as induction rates and route of delivery changed in Montgomery County and how these compared to overall trends in the United States.
- Assessed how infant outcomes such as calculated gestational age and birthweight changed in Montgomery County and how these compared to overall trends in the United States.
- Generated a report displaying and comparing results with US trend data.
- Presented results to mentors and peers.
- Addressed questions about the study.

Centers for Disease Control and Prevention Atlanta, GA 2011
Mycotic Diseases Branch - Internship

- Gathered and revised literature to revamp the Fungal Diseases webpage.
- Designed fungal fact sheets which served as a multimedia tool to inform and educate the general public.
- Utilized social media, such as Twitter, for educational outreach purposes.

Centre College Danville, KY 2008
Analytical Chemistry – Sewage Plant's Effect on Water

- Collected samples of creek water at three different sites to analyze six different parameters in the water.
- Designed experiments to test and calculate amounts of nitrate and phosphate levels in the water.
- Constructed graphs and a report to demonstrate the sewage plant's effects on the water.

TEACHING EXPERIENCE

University of Louisville Louisville, KY Spring 2017
PHEP 650 Advanced Topics in Epidemiology – Communicable Disease
Volunteer Teaching Assistant

- Coordinated with the course director to create the course objectives and syllabus.
- Participated in weekly meetings with the course director to discuss class progress.
- Developed the content for several classes that met the course objectives.
- Lectured several classes and led in-class activities.
- Utilized Blackboard to distribute supplemental reading material and assignments to students.
- Helped construct the midterm exam.
- Held office hours to meet with students and was available via email correspondence.

Centre College Danville, KY Spring 2009
CHE 131 Atomic and Molecular Structure Laboratory Assistant

- Mentored students on laboratory safety and experimental techniques.
- Answered questions on experimental design and laboratory techniques.
- Gathered equipment and materials to set up lab stations.
- Assessed and graded lab notebooks.

OTHER WORK EXPERIENCE

University of Louisville Louisville, KY 2013-Present
School of Interdisciplinary and Graduate Studies - Graduate Assistant

- Compiled and analyzed data from Professional Development, Life Skills, Academic Development, and Networking (PLAN) workshop evaluations to help assess and improve content throughout the academic year.
- Conducted data analysis for reports on student stipend sources which were presented to the Office of the President.
- Designed SAS Visual Analytics interactive reports for Graduate Student Recruitment, Admissions & Assistantship Data (GRAAD).
- Worked in teams with the graduate school faculty and staff to organize and prepare for bi-yearly graduation ceremonies.
- Coordinated the search for a student spotlight entry for the graduate school webpage, in order to highlight an exceptional student each month and advertise UofL graduate programs.
- Updated and maintained the graduate school social media sites including Facebook, Twitter, and LinkedIn.
- Constructed monthly emails for the graduate student body to advertise various activities and graduate student opportunities.

Montgomery County Sheriff's Office Dayton, OH 2012-2013
Regional Dispatch Center - 911 Call Evaluator

- Processed 911 calls using Vesta phone system, MapStar, and Computer Aided Dispatch simultaneously.
- Utilized both verbal and written communication in order to quickly gather pertinent information required for emergency response and relay that information to the police and fire dispatchers.
- When appropriate, provided CPR or first aid instructions during medical emergency calls.
- Interviewed callers through a series of appropriate questions to gather information needed for the responding officer and to assess scene safety.
- Remained on the line with callers who were in imminent danger to provide officers with real-time information, to reassure the caller help was on the way, and continually assess scene safety.

Wright State University Dayton, OH 2011-2012
Master of Public Health - Graduate Assistant

- Organized and provided disability services for students with special needs.
- Assisted professors in gathering materials and references for various research projects.
- Compiled student reviews at the end of each quarter to help improve teaching methods and course content.
- Recorded class sessions for off-site students and for professors to use as a review tool.

VOLUNTEER EXPERIENCE

University of Louisville Louisville, KY 2014-2015
Paul Weber Award for Departmental Excellence in Teaching
Committee Member, Graduate Student Representative

- Reviewed department applications for the Paul Weber Award for Departmental Excellence in Teaching.
- Worked with committee members to select finalists for the award.
- Provided feedback for departments that did not move on to the second round of the application process.
- Attended and evaluated a departmental meeting of a contending department.
- Collaborated with committee members to select the award recipient and assisted in constructing an award letter.

Carlisle High School Carlisle, OH 2012
Volunteer Assistant Varsity Coach

- Assisted with practice four times a week, which included leading drills, demonstrating techniques, and organizing scrimmages.
- Mentored young players by answering their questions, talking through their problems, and providing advice on soccer and college.
- Recorded statistics for varsity players each game.
- Coordinated weekly endurance practices for both varsity and junior varsity teams.
-

Centre College Danville, KY 2008-2010
Big Brothers Big Sisters – Big Sister

- Prepared and organized activities to participate in with my "little sister".
- Helped to solve problems and lead by example.
- Volunteered at Big Brother Big Sister events.
- Communicated with BBBS Coordinator and family about the progress of the match.

Centre College Danville, KY 2008-2009
Habitat for Humanity

- Worked as a member of the volunteer team to help build a home for an underprivileged family.
- Used tools to measure, cut, and hang vinyl siding on the outside of the home.
- Aided others as needed during the construction of the home.

HONORS/AWARDS

- Graduate Dean's Citation Award – May 2017
- 2017 Department of Epidemiology and Population Health Travel Grant – June
- Outstanding Graduate Student recognized May 18, 2016
- 2016 Department of Epidemiology and Population Health Travel Grant – October

- 2016 School of Public Health and Information Sciences Travel Grant – October
- 2016 Department of Epidemiology and Population Health Travel Grant – May
- 2016 School of Public Health and Information Sciences Travel Grant – May
- 2016 Graduate Student Council Travel Grant
- 2016 Graduate Student Council Research Grant
- 2016 Publishing Academy Participant
- 2015 Grant Writing Academy Participant
- 2015 EIS David J. Sencer Scholarship Recipient
- 2012 Delta Omega Honorary Society in Public Health – Student Inductee
- Honor Society of Phi Kappa Phi

PUBLICATIONS, POSTERS, AND REPORTS

- **Hagemeyer ANB**, Sears CG, & Zierold KM. Differences in self-reported respiratory symptoms among adults exposed to coal ash compared to non-exposed adults. IN DRAFT

- Odoh C, Hanchette C, Sears L, Polivka B, **Hagemeyer ANB**, Brock GN, & Zierold KM. Design and protocol for a community-based cross-sectional study on coal ash exposure and neurobehavioral effects among children in Louisville, KY. IN DRAFT

- **Hagemeyer ANB**, Sears L, Polivka B, Brock GN, Hanchette C, & Zierold KM. Association between metal exposure and depression problems in children residing near coal ash storage facilities. Poster Presentation at the Society for Epidemiologic Research Conference held in Seattle, Washington; June 2017.

- **Hagemeyer ANB**, Sears L, Polivka B, Brock GN, Hanchette C, & Zierold KM. Association between metal exposure and anxiety problems in children residing near coal ash storage facilities. Poster Presentation at the Society for Pediatric and Perinatal Epidemiologic Research Conference held in Seattle, Washington; June 2017.

- **Burns AN**, Sears CG, & Zierold KM. Self-reported respiratory illness in adults living in the surrounding area of a coal ash storage facility. Poster Presentation at the American Public Health Association Conference held in Denver, Colorado; October 2016.

- Ebron DL, **Burns AN**, & Paton SJ. Health Profiles: An Analysis of Births in Montgomery County, OH. Dayton, Ohio: Public Health - Dayton & Montgomery County; April 2012.

SKILLS

Statistical Software: SAS, R, SPSS, Epi Info
Computer: Microsoft Word, Excel, PowerPoint, Access, Outlook, Windows 10, MAC OS X, Internet Explorer, LYX, Python, Java, Vesta, MapStar, CAD, Faxing, Scanning, Copying.
Laboratory: filtrations, distillations, purifications, crystallizations, chemical preparations, extractions, gas, column, layer chromatography, mass spectroscopy, NMR, IR.
Other: great organizational skills, well-defined communication skills, team work, leadership.