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Wenzel, Shawn W. ***Evaluation of Exposure to Second-hand Toxic Substances in the Homes of Construction Workers***

Abstract

This study investigates the potential for construction workers, on an urban reconstruction project, to transport lead, mercury, and benzo(a)pyrene contaminated soil home leading to possible exposure of family members. To accomplish this goal, three techniques were conducted 1) soil testing reports were analyzed and compared to the Minnesota Pollution Control Agency's Short-Term Soil Reference Values, 2) an extensive literature search was performed to identify the health effects associated with each toxin, and 3) a gap analysis was conducted on three contractor safety plans in regards to prevention of second-hand contamination and comparing these plans to best industry practices. The results indicate that the potential for worker exposure to on-site toxins existed and exceeded the MPCA's recommendations. The evaluation performed, on the contractors' safety plans demonstrated deficiencies in several critical areas identified as best industry practices to avoid contaminating families. Research conclusions indicate the need for implementation of recommended procedures, verification that necessary safety and health procedures are in place, and employing control measures to prevent or minimize exposure to prevent transporting harmful toxins home and exposing family members.

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Chapter I: Introduction

In 1995, the National Institute of Occupational Safety and Health (NIOSH) published a study which found "…that contamination of workers' homes is a worldwide problem, with incidents reported from 28 countries and from 36 States in the United States" (p. 98). According to the Environmental Protection Agency (EPA), research indicates that the potential for second-hand exposure from workplace contaminants has occurred in over 40 business sectors. Included in the EPA report were toxins transported from industries in the areas of construction (EPA, 2008).

Construction Industry

Construction workers are exposed, unknowingly, to hazardous materials every day. As a result of this exposure, employees might, unintentionally, carry materials such as mercury, radioactive material, lead, asbestos, pesticides and arsenic, away from the jobsite and expose members of his/her household (NIOSH, 1995). NIOSH (1995) found that toxic substances are transported from a construction site by way of vehicles, work boots, clothing, skin, hair, tools, and other items. The transfer of these materials to a worker's home can result in various health effects to his/her family/household (NIOSH, 1997). The Agency for Toxic Substances and Disease Registry (ATSDR) (2012) states that second-hand toxins are specifically harmful to employees' families; this point is dissimilar to air contaminants or chemical spills that may have an effect on the entire region. Children are most susceptible to the harms of contaminants (toxins, etc.) due to their higher metabolic rates and developing organs (Whelan et al., 1997).

Research Studies

According to a meta-analysis of research studying take-home lead exposure, children living in households with lead-exposed workers are at an increased risk for elevated blood lead levels (Roscoe, Gittleman, Deddens, Petersen, & Halperin, 1999). Lead levels were greatest in children of those employed in "…work in battery production, ceramics, radiator repair, laborer jobs, construction, and firing ranges" (Roscoe et al., 1999, p. 479).

Based on research from Hipkins, Materna, Payne, and Kirsch, (2004), "it is well documented that children under age 6 years and the fetus are especially vulnerable to neurologic damage affecting learning and behavior with potential for life-long impact" (p. 845).

Contaminates transported from construction sites often are invisible or too small to be noticed. Family members and friends may not realize the risk of exposure by way of touching a contaminated worker, handling his/her clothing, or cleaning a house that contains hazards transported from a jobsite (NIOSH, 2002). Workers need to be trained on proper safety protocols. Professionals in the safety industry have been requesting further studies with regards to at-risk groups, tighter monitoring of regulations, to avoid the transfer of hazardous substances from work areas, and further training pinpointing the dangers associated with transporting contaminants home from one's place of employment (NIOSH, 2002).

Sanderson et al. (1999) and Miller (2005) stated:

> To prevent take-home exposures, workers exposed to hazardous substances should be counseled about hygiene measures to take before leaving the workplace. Behaviors, such as changing from contaminated work clothes and showering at the worksite, are simple actions that a worker can take to prevent bringing known toxins, such as lead, beryllium, and asbestos, home to their families (as cited in Chey & Buchanan, 2008, p. 721).

Site of Study

Construction projects encompass several forms, including industrial, commercial, and residential. In each of these sectors, major efforts are employed to provide contractor and worker safety training relative to all aspects of the job. One specific project involved an urban reconstruction project in Minnesota. It was coined the largest infrastructure project in Minnesota history. The project entailed complete removal and replacement of the underground utility system (i.e. water main, sanitary and storm sewer, and associated appurtenances), pavement, sidewalks, and installation of rail lines between Saint Paul, Minnesota and Minneapolis, Minnesota. Nearly an 11 mile corridor required subsurface excavation to install the necessary improvements. As a result, existing soil contaminates were uncovered and remediation was conducted. The researcher was involved in this project as an intern and had an opportunity to attain data collected for the project regarding contaminated soils present within various segments of the project. Using this information, the author analyzed the data to determine worker and potential family exposure to known toxins.

Statement of the Problem

Construction workers, on an urban reconstruction project potentially transport lead, mercury, and benzo(a)pyrene on their clothes and boots home and risk exposure to their family members.

Purpose of the Study

The purpose of this study was to investigate the possible exposure of workers to lead, mercury, and benzo(a)pyrene contaminated soils while constructing the urban reconstruction project and develop a plan to reduce or prevent second-hand exposure to these toxic substances from the site. Identifying best practices in order to minimize potential exposure is integral in eliminating the source of contamination in the homes of construction workers. The study intends to analyze the potential harmful levels of lead, mercury, and benzo(a)pyrene in the soil where workers perform construction activities and to publish procedures to assist contractors, in the construction community, in identifying and controlling these hazards.

Research Questions

This study sought answers to the following research questions:

1. What levels of lead, mercury, and benzo(a)pyrene were present in the soil where workers performed construction activities on a specific urban reconstruction project?
2. How did the measured concentrations of lead, mercury, and benzo(a)pyrene in soil samples compare to acceptable levels as defined by the Minnesota Pollution Control Agency's standard for short-term exposure?
3. What are the possible physiological effects of lead, mercury, and benzo(a)pyrene contaminants on the workers and their families?
4. What preventative measures should occur in order to minimize the transport of toxic materials home from a construction site and, thus, curtailing exposure to a person's household?

Importance of the Study

The lack of comprehensive studies, documenting how effective workplace safety protocols are at preventing contamination in the home of workers, makes this study significant. The topic of take-home exposures was not on the current National Occupational Research Agenda (NORA) Sector Agenda for Construction. According to NIOSH (2002), however, the "research priorities fit within the NORA framework – and particularly within its priority area *Special Populations at Risk*" (p. 10).

Limitations of the Study

The following limitations apply to this study:

1. The focus of this study was on an urban reconstruction project in Minnesota.
2. This study is limited to workers' exposure to toxic substances on the construction site and within the project limits.
3. A survey of construction workers was not conducted due to the seasonal nature of the industry.
4. The data was limited by the accuracy of the soil collection methods and the chemical measurements in each sample from the Soil Testing Company XYZ.
5. The results are limited to the researcher's knowledge, education, and accuracy of the data collected by the state agency.
6. The review of the contractors' safety plans is limited to information contained within each company's manual. No training documents were evaluated.

Methodology

To accomplish the objective of this study, three methods were employed 1) an extensive literature search identifying the extent of the problem, health effects of contaminants on workers and their families, best industry practices, and sampling methods were conducted, 2) documentation prepared for the urban reconstruction project, regarding soil remediation, was analyzed for potential exposure to the workers and their families, and 3) an analysis compared existing contractors' safety plans with best practices in order to minimize take-home exposure.

Definition of Terms

Asbestos. Asbestos is the name given to a group of naturally occurring minerals used in certain products, such as building materials and vehicle brakes, to resist heat and corrosion (OSHA, 2002, p. 1).

Benzo(a)pyrene. Benzo(a)pyrene is a polycyclic aromatic hydrocarbon (PAH). PAHs are a result of incomplete combustion of fossil fuels (EPA, 2011).

Beryllium. "Beryllium is a metal that is found in nature, especially in beryl and bertrandite rock. It is extremely lightweight and hard, is a good conductor of electricity and heat, and is nonmagnetic" (OSHA, 2012, para. 1).

Lead. "Lead is a highly toxic metal used in products such as paint, ceramics, pipes, solders, gasoline, batteries, and cosmetics" (National Institute of Health [NIH], 2013, para. 1).

Mercury. "Mercury is a naturally occurring element that is found in air, water and soil. Elemental or metallic mercury is a shiny, silver-white metal and is liquid at room temperature. If heated, it is a colorless, odorless gas" (EPA, 2012, para. 1).

Minnesota Pollution Control Agency (MPCA). "The Minnesota Pollution Control Agency monitors environmental quality, offers technical and financial assistance, and enforces environmental regulations. The MPCA finds and cleans up spills or leaks that can affect our health and environment" (MPCA, 2013, para. 1).

National Institute of Occupational Safety and Health (NIOSH). "The National Institute for Occupational Safety and Health (NIOSH) is the federal agency responsible for conducting research and making recommendations for the prevention of work-related injury and illness" (NIOSH, 2012, para. 1).

1,2,4,Trimythlbenzene. "Trimythlbenzene (TMB) is a colorless, flammable liquid. TMB occurs naturally in cold tar and petroleum crude oil" (EPA, 1994, p. 2).

Chapter II: Literature Review

The purpose of this study was to 1) investigate the potential exposure of workers to soils contaminated with lead, mercury, and benzo(a)pyrene while constructing an urban reconstruction project and 2) develop a plan to reduce or prevent second-hand exposure to these toxic substances from the site. The current lack of hygiene practices on the part of construction workers places families at risk for exposure to harmful chemicals. These potential occupational second-hand exposures may result in serious health effects. The literature review will focus on the following topics as related to this study: potential family health effects, extent of the problem in construction, best industry practices used to prevent and/or reduce the potential exposure to workers' families, and sampling methods used to identify the potential for take-home contaminants.

Health Effects

Few studies have analyzed the degree of construction worker exposure and the resulting health effects on a worker's family (NIOSH, 2002). Researchers, nevertheless, are able to link specific chemicals to its toxicological effects. In the following sections, studies pertaining to the human health effects of lead, mercury, and benzo(a)pyrene are discussed.

Lead. The primary routes of exposure are inhalation of lead dust and ingestion from contact with lead-contaminated skin, clothing, food, and drinking water (NIOSH, 1995; Swartz, 2001). Once lead enters the body, it is released into the blood stream and dispersed throughout the body (NIOSH, 1995). Researchers have found that over 90% of lead in the body is stored in the bones and remains for several years (Swartz, 2001).

Lead has long been recognized as a toxic compound with both acute and chronic effects (Swartz, 2001). Physiological ramifications of short-term exposure to lead include fatigue, intestinal pain, irregularity, and neurological disorders (Swartz, 2001). Greater concentrations may result in unconsciousness and even death (NIOSH, 1995). Dangerous health effects, such as elevated blood pressure, reproductive issues, nervous system damage, muscle and joint pain, cognitive changes, and organ failure, may occur long-term or short-term exposure at higher concentrations (ASTDR, 2010; Swartz, 2001).

Health care professionals measure the concentration of lead in the body (e.g. Blood Lead Level [BLL]) in micrograms of lead per deciliter of blood (µg/dL) (Swartz, 2001). Due to the variance in human physiology, a quantified amount of lead in the body does not necessarily signify exposure to lead, but the resulting health effects do correlate to BLLs (Swartz, 2001). Table 1 provides a brief summary of the severity at different BLLs in adults and children.

Table 1

Severity of Health Issue and Blood Lead Levels in Adults and Children

Severity	Adult BLL (µg/dL)	Children BLL (µg/dL)
Normal	<10	<5
Elevated	>25	>5
Serious	>40	-
Severe	>60	-

(Washington State Department of Labor & Industries [L&I WA], 2000; Meyer et al., 2003)

Symptoms of lead poisoning slowly increase as an adult's BLLs increase. Adults, with BLLs between 20 and 40 µg/dL, exhibit signs of hypertension, reduced auditory functioning, numbness, muscle and joint pain, and potential reproductive issues (L&I WA, 2000; ATSDR, 2010). When BLLs are in the 40 to 50 µg/dL range, adults may develop serious health effects, particularly exhaustion, headaches, and bone marrow suppression (L&I WA, 2000; Swartz, 2001). At levels greater than 80 µg/dL, hematological and renal systems are most commonly affected (Swartz, 2001). In the hematological system, this causes a hazardous decrease in the blood's capacity to transport oxygen (anemia) (L&I WA, 2000; Swartz, 2001). Whereas, in the renal system, the kidney's ability to filter contaminants (e.g. lead) from the bloodstream is severely affected and may cause renal failure (Swartz, 2001).

Research also indicates that children and mothers (pregnant and lactating) exposed to lead, suffer from negative health effects at lower BLLs (ASTDR, 2010; Centers for Disease Control and Prevention [CDC], 2010; Minnesota Department of Health [MDH], 2005). In contrast to adults, a lower level of lead exposure causes adverse health effects in children (Handler & Brabander, 2012). The CDC (2012) recently reduced the BLL reference value for children from 10 µg/dL to 5 µg/dL. The lower BLL for children increases the number classified as having lead intoxication by 1470% (Handler & Brabander, 2012). In 2011, an estimated 204,000 of 3.5 million tested U.S. children, less than six years of age, had BLLs $\geq$ 5 µg/dL, (CDC, 2011). Current research indicates that adverse health effect can potentially start to occur at this lower BLL. The CDC (2012) now states that there is no safe level of lead exposure.

Children under the age of six are especially susceptible to the effects of lead exposure due to neurological development (Bellinger, 2008). For this population group, low levels (e.g. BLLs <10 µg/dL) of lead exposure can potentially cause: reduced IQ, learning disabilities, attention deficit hyperactivity disorders, and poor problem solving skills (Bellinger, 2008). Lead poisoning cases, in which blood lead levels were greater than or equal to 45 µg/dL, showed that children typically exhibited symptoms such as neurological issues and anemia (Godwin, 2009). Studies, further, have shown that children with blood lead levels of 70 to 100 µg/dL may develop cognitive disabilities, growth retardation, coma, and even death (ASTDR, 2012; Godwin, 2009; National Safety Council [NSC], 2009).

Another important population group to consider, in terms of lead exposure, is pregnant and lactating women. Lead, in the blood of a pregnant woman, from past or current exposures, has the ability to transfer to the fetus through the placenta. Medical research has shown that lead is stored in bone. When a woman becomes pregnant, lead may be released back into the bloodstream (ATSDR, 2010). As a result, the baby may be born with an elevated lead level in the blood (ASTDR, 2010; MDH, 2005). Lead exposure can continue through breastfeeding as well. An infant's BLLs should be monitored (MDH, 2005). The health effects from lead exposure are consistent with those exhibited in adults and children at the associated BLLs (MDH, 2005).

Mercury. Several factors determine whether a person will exhibit health effects associated with mercury exposure. These factors consist of the amount of mercury, the length of exposure, age and health of the individual, and mode of contact (ATSDR, 1999; EPA, 2012). Studies have shown that mercury poisoning exhibits a wide range of symptoms and responses within humans (ATSDR, 1999). The following sections describe the health effects associated with metallic mercury and inorganic mercury exposures.

Inhalation is the primary route of exposure and results in nearly 80% of metallic mercury vapor absorption (Argonne National Laboratory [ANL], 2005; ATSDR, 1999). Metallic mercury is lipophilic in nature, and, thus, it is distributed throughout the body upon absorption into the bloodstream through inhalation and remains in a person's adipose tissue (ATSDR, 1999). The major target, following inhalation of metallic mercury, is the central nervous system. Researchers have observed comparable neurological effects of acute and chronic exposures

(ATSDR, 1999). Acute symptoms include tremors, emotional changes, insomnia, muscle weakness, headaches, and reduced motor and cognitive function (ATSDR, 1999; EPA, 2012). Permanent damage may occur if there is an increase in amount and length of time one is unprotected from mercury (ATSDR, 1999). At high-exposure levels, respiratory, cardiovascular, and gastrointestinal effects may occur (ATSDR, 1999). Ingesting small amounts of metallic mercury, about 0.1 mL, does not, typically, exhibit signs of poisoning due to malabsorption of metallic mercury in the gastrointestinal tract (ATSDR, 1999; Wright, Yeoman, & Carter, 1980). Conversely, dangerous effects may occur when small quantities of liquid mercury evaporate and the vapors are inhaled (ATSDR, 1999). Subsequently, comparable health effects to a person, with regard to mercury, are related to the route of entry. Inorganic mercury tends to have the greatest negative health ramifications.

When inorganic mercury is ingested, the target organ is the kidney. Progression of kidney damage leads to renal tubule and filtering disorders (ATSDR, 1999). Studies have also shown additional effects such as gastrointestinal disorders, skin rashes, and lack of muscle strength (EPA, 2012). According to the World Health Organization (WHO) (2009), individuals who are acutely exposed to elevated amounts of inorganic mercury may experience problematic effects to the gastrointestinal tract. In contrast to metallic mercury, inorganic mercury will not typically transfer through the blood brain barrier and cause damage to the central nervous system, but peripheral nervous system effects have been documented (ATSDR, 1999).

“Pink disease” has been newly diagnosed in adults in addition to being previously reported in children (ATSDR, 1999, p. 305). This illness is associated with people who have inhaled, ingested, or had dermal contact with mercury. The symptoms include “severe leg cramps, irritability, erythema and subsequent peeling to the hands, nose, and soles of the feet" (ATSDR, 1999, p. 305).

As with other chemicals, a developing fetus and infants are highly susceptible to the toxic effects of mercury (ATSDR, 1999). An unborn child may be exposed to mercury through the placenta, and infants can be exposed via breast milk.

Benzo(a)pyrene. Benzo(a)pyrene, a PAH, is classified by the U.S. Department of Health and Human Services (HHS) as a known animal carcinogen (ATSDR, 1995). The International Agency for Research on Cancer (IARC) and the EPA both listed it as potentially carcinogenic to humans (ATSDR, 1995). Researchers have recognized it as a toxic compound with both acute and chronic health effects from occupational exposure. Specific health consequences related to occupational exposures are documented in the toxicological profile for benzo(a)pyrene (ATSDR, 1995).

Health effects of PAH may result from airborne particles entering the lungs, gastrointestinal tract, and being absorbed through the skin. Physiological effects of introducing benzo(a)pyrene into the body include pulmonary complications, gastritis, and neurological complications, such as cognitive changes and headaches. The recognized consequences of PAH exposure in the workplace are "chronic bronchitis, chronic cough irritation, bronchogenic cancer, dermatitis, cutaneous photosensitization (abnormally heightened reactivity of the skin to sunlight), and pilosebaceous reactions (pertaining to a hair follicle and its oil gland)" (ATSDR, 1995, p. 38). Greater concentrations may result in damage to red blood cells, liver and kidneys, and even in death (ATSDR, 1995). Chronic poisoning or acute exposure at higher concentrations may have severe effects, such as leukemia, lymphoma, renal, and bladder cancers (ATSDR, 1995).

Given the adverse health consequences associated with lead, mercury, and benzo(a)pyrene in the workplace, what is the scale of the issue for workers and their families in the construction industry?

Extent of the Problem

The scale of the issue, related to second-hand exposure from contaminated soils at construction sites, is not clearly defined. According to the EPA, soil, especially in urban areas, often is contaminated with lead (e.g. from years of leaded gasoline and deteriorated lead paint), mercury (e.g. factory emissions deposited from rain or snow), and benzo(a)pyrene (e.g. industrial emissions deposited from rain or snow). Construction workers are readily exposed to many contaminants in the ground, but lead is the most researched. In the subsequent review of literature, occupational exposure to lead, mercury, and benzo(a)pyrene contaminated soil is discussed in further detail.

Lead. "Lead binds tightly to soils, and eight decades of leaded gasoline combustion and past industrial emissions have left a legacy entrained in soil" (Levin et al., 2008, p. 1286). Metropolitan areas have approximately 800-1,200 µg/g of lead in soils (Duggan & Inskip, 1985; Lanphear, 1998). Soil with a total lead content of 400 parts per million (ppm) (or 400 micrograms per gram[µg/g]) is regarded as unacceptable for children's recreation areas, and soil containing total lead greater than 1200 ppm (or 1200 µg/g) is considered a hazard for everyone (EPA, 2001). Given the prevalence of lead, construction workers, who are performing activities in bare soil, have a high potential for personal and take-home lead exposure. No studies directly associated with lead contaminated soil from construction jobsites and second-hand exposures were identified. The literature review for lead, therefore, contains research of occupationally exposed workers and potential for contaminating their families.

In one study, researchers investigated 37 families of lead exposed construction workers and compared them to a control group containing 22 families in the same area with unknown lead exposure in order to evaluate the scope of second-hand lead exposure (Piacitelli, Whelan, Sieber, & Gerwel, 1997). Samples were collected by industrial hygienists from the homes and vehicles of each family in the study. Additionally, the investigators surveyed the workers to assess the working conditions and procedures followed at the jobsite and in their homes. Table 2 describes the results of the survey.

Table 2

Questionnaire to Lead Exposed Construction Workers in New Jersey (1994)

Questions	Percentage
Received training about dangers of lead	50.0
Workers provided company-laundered work clothes	28.6
Shower facilities	32.1
Showered before leaving work	17.9
Changed clothes prior to leaving work	50.0
Transported or wore work shoes home	46.4
Laundered work clothes at home	90.9

(Whelan et al., 1997, p. 1353)

When contrasted to the base group, it was determined that a lead exposed worker's hands were 10 times more tainted, the quantity of lead in areas where worker's changed clothes was considerably greater, and a significant difference in the amount of lead was found on surfaces in worker's automobiles (Piacitelli et al., 1997). The researchers concluded that measures to reduce take-home lead contamination were rarely practiced by the workers and companies, which increased the likelihood of exposing family members to lead (Piacitelli et al., 1997). A lack of hazard communication or training is evident in these results. The study is limited in its population size (29), of which 26 are in the New Jersey Adult Blood Lead Epidemiology and Surveillance (ABLES) registry. Nonetheless, the research implies that construction workers exposed to lead on the job, along with improper personal hygiene, were major sources of lead contamination.

When lead is present on a household surface, an increased risk of ingestion is present among adults and children (Piacitelli et al., 1997). According to the CDC (2012), ingestion of dust particles is the primary route of exposure for children. Parents understand that children crawl on the floor and, until a certain age, put everything in their mouths. "All it takes is the lead dust equivalent of a single grain of salt for a child to register an elevated blood lead level" (NSC, 2009, p. 1). Young children simply have not developed the sense of judgment to stay away from hazards (National Research Council [NRC], 1993).

Researchers have analyzed the correlation between BLLs of children and families with lead exposed workers. One such project, conducted by Roscoe et al. (1999), examines published and unpublished reports from 1987 to 1994 of children with a family member who is occupationally exposed to lead. They approximate that "48,000 children are at an increased risk of lead exposure by living in homes with lead exposed workers, and that about half may have BLLs of 10 µg/dL or greater" (Roscoe et al., 1999, p. 480). According to the CDC (2011 & 2012), an elevated blood lead level is classified as a child having a BLL greater than 5 µg/dL and an adult with a BBL greater than 25 µg/dL. Further research found that "children of lead-exposed workers are six times more likely to have a BLL of 10 µg/dL or greater than were children of neighbors who were not occupationally exposed to lead" (Whelan et al., 1997, p.

1354). The results, consequently, indicate a need for testing children of occupational lead exposed workers as well as enforcement of workplace hygiene practices (Piacitelli et al., 1997; Roscoe et al., 1999).

Mercury. Mercury is a naturally occurring metal in the environment and released into the air, soil, and water from human activities (e.g. coal-fired electricity plants) (ATSDR, 1999). Similar to lead, mercury binds tightly to soil. In the United States, the persistent levels of mercury in nature vary from less than 0.02 milligrams to approximately 6 milligrams of mercury per kilogram of soil (mg/kg) (ANL, 2005). The MPCA defines the maximum concentration of mercury in soil as 0.7 ppm (or 0.7 mg/kg) when deciding whether to transport mercury-contaminated soils to an out-of-state hazardous waste site (MPCA, 2007).

The amount of mercury that is potentially absorbed into the body following ingestion, inhalation, or contact will vary from location to location (ATSDR, 1999). A worker's mercury exposure may increase as a result of skin contact with mercury-contaminated soil (ATSDR, 1999). Employees, further, have the potential for ingestion of mercury-contaminated soil if they do not exercise proper hygiene practices prior to eating (ATSDR, 1999). Children may be exposed to mercury via ingestion or skin contact with mercury-contaminated soil (ATSDR, 1999). In a study of people living near a former industrial site contaminated with mercury, research shows that neighboring children had a high rate of ingestion exposure from the soil (NuBlein, Feicht, Schulte-Hostede, Seltmann, & Kettrup, 1995). No documented research, however, was located that examined the amount of mercury in the body following ingestion, inhalation, or dermal contact and the potential consequences. There is a knowledge gap existing between a construction worker's exposure and the adverse effects to the worker's family. As a result, the review of literature will focus on the potential for second-hand exposure to mercury as studied in other industries.

In the latest National Occupational Exposure Survey (NOES) from 1980 to 1983, NIOSH projected that "…67,551 workers, including 21,153 women in 2,877 workplaces were potentially exposed to mercury in the workplace" (as cited in ATSDR, 1999, p. 453). The presence of mercury at home may result from carrying mercury contaminated clothing and shoes from a jobsite to a residence (as cited in ATSDR, 1999; Hudson et al., 1987; Zirschky, 1990). Mercury particles can become embedded in a worker's clothing, and high levels of mercury can be found in a number of washing machines and areas where work clothes are stored (Danziger & Possick, 1973; Hudson et al., 1987). Mercury soaked clothing, gloves, and shoes transported home by workers, at a chloralkali plant in Tennessee, resulted in an elevated level (0.92 $\mu g/m^3$) of mercury in the air and the amount of exposure to family members (ATSDR, 1999). According to ANL (2005), the normal concentration of mercury in air ranges between 0.01 and 0.02 microgram per cubic meter ($\mu g/m^3$).

The most vulnerable are children whose parents are employed where mercury is used without protective clothing or shoes (ATSDR, 1999). The risk to children has increased with occupational mercury exposure (Hudson et al., 1987). In a study conducted by Hudson et al. (1987), researchers discovered a mercury level over five times greater than their peers in children of thermometer manufacturing plant employees. This study, and similar reports, indicates a correlation between a worker's exposure and transferring mercury home on garments and shoes.

No research studies were found in literature related to second-hand exposure to metallic mercury from contaminated family members. Researchers, however, recognize that metallic mercury is harmful to human health in very small quantities (ATSDR, 1999). If mercury-contaminated clothing is not stored in a sealed container, children may be exposed to dangerous vapors (ATSDR, 1999; Wendroff, 1990). "Metallic mercury and its vapors are extremely difficult to remove from clothes, furniture, carpet, floors, walls, and other such items" (ATSDR, 1999, p. 8). Consequently, mercury may remain embedded in contaminated surfaces and/or materials for an extended period of time (e.g. months or years) where potential health risks will continue to be an issue (ATSDR, 1999; Wendroff, 1990).

Benzo(a)pyrene. As a PAH, benzo(a)pyrene has been identified in air, water, sediment, soil, and food. According to ATSDR (1995), studies are needed in areas with known PAH contamination in order to determine concentration information. In addition, research is necessary to identify the potential for ingestion or skin contact with contaminated soil (ATSDR, 1995). No studies identify the potential occupational exposure risks. A lack of research exists that studies the connection between a worker's exposure and adverse effects to the worker's family.

There is an identifiable gap in research related to the degree of exposure from lead, mercury, and benzo(a)pyrene contaminated soil on a jobsite. It is necessary to correlate exposure to these elements in other industries to how employees may reduce the potential for carrying hazardous chemicals home and to their families.

Best Industry Practices for Not Contaminating Families

The Occupational Safety and Health Act of 1970 requires companies to provide a safe workplace for their employees. Pursuant to this Act, OSHA standards were developed to protect workers from unsafe conditions and situations. For example, OSHA's Lead Standard, 29 CFR 1926.62, applies to a worker's inhalation of 50 micrograms of lead per cubic meter of air or greater over an eight-hour period (OSHA, 2003). This regulation is not sufficient to avoid second-hand exposure to family members due to the fact that employees exposed to less than 50 $\mu g/m^3$ of lead may potentially transport lead home. The standard does not prevent workers from carrying lead contaminated soil home on their clothes and boots (Piacitelli et al., 1997; Hipkins et al., 2004). Similarly, OSHA's Mercury Standard, 29 CFR 1926.55, is associated with occupational exposure to airborne mercury vapor (OSHA, 2007). The regulation fails to address the possible contact from mercury contaminated soils. NIOSH has identified these inadequacies in the standards and developed best industry practices to protect workers' families (Piacitelli & Whelan, 1996). Various techniques were identified in NIOSH's 1995 report to Congress.

- Reducing exposures in the workplace;
- Changing clothes before going home and leaving soiled clothing at work to be laundered by the employer;
- Storing street clothes in separate areas of the workplace to prevent their contamination;
- Showering before leaving work;
- Prohibiting taking toxic substances or contaminated items home;
- Preventing family members from visiting the workplace;
- Laundering separately from family laundry when it is necessary to launder contaminated clothing at home;
- Informing workers of the risk to family members from home contamination and ways to prevent it (p. 54).

Additionally, good hygiene practices should be performed throughout the workday, especially while eating and smoking (L&I WA, 2000). In an analysis of 88 hand-wipe samples, Virji, Woskie, and Pepper (2009) found that good hygiene practices directly correlates to lower lead levels on workers' hands. It may be necessary to use visual tools to stress the point (Sofge, 2003). Following up with toolbox talks about the toxicity and potential effects on family members will remind the workers of the value of good hygiene (Sofge, 2003).

NIOSH (1991) also published guidelines to minimize worker and family exposure to lead. Recommendations for employers of construction workers are as follows:

- Conduct air monitoring by a qualified professional;
- Implement engineering controls (i.e. ventilation, wetting, vacuum, and contract specifications);
- Practice personal hygiene (i.e. hand washing facility, showering, changing into work clothes, and employer laundering of work clothes);
- Post warning signs around lead contaminated work areas;
- Provide personal protective equipment (i.e. protective clothing and respirator);
- Employ medical surveillance program to monitor the BLLs in workers;
- Train workers on potential adverse health effects, early recognition of lead intoxication, understanding material safety data sheets, personal hygiene, use and care of personal protective equipment, and safe work practices (p. 1).

Active participation from local, state, and federal agencies is also important for reducing exposure to lead (Levin et al., 2008). The involvement should include:

- Monitoring lead in water, air, and soil;
- Enforcing laws that control lead contamination;
- Educating specific populations about lead and exposure control;
- Improving exposure modeling techniques;
- Accounting for all sources of exposure;

- Conducting research and ongoing evaluation of lead poisoning prevention activities (Levin et al., 2008, p. 1291).

Best industry practices are vital to the safety of workers and their families. According to the Construction Industry Institute (CII), "CII member companies that use best practice approaches for safety fare almost seven times better than non-member companies" (NRC, 2007, p. 20). When properly trained, employees will be prepared to make educated decisions based on an understanding of the family hazards associated with lead and mercury contaminants in the construction industry. Employers should distribute information on identifying hazards and effective techniques to reduce exposure. Minimizing exposure is the best strategy to keeping workers and their families safe (Sofge, 2003). It is, further, important for employees to communicate with their family physician regarding occupational exposures and potential exposure to family members (Sofge, 2003). A concerted attempt is necessary to ensure compliance by companies and employees with procedures intended to avoid contamination outside the workplace (Piacitelli et al., 1997). In association with this effort, sampling methods should be part of a contractor's safety plan.

Sampling Techniques

The implementation of proven sampling methods is a proactive approach to determining the potential for bringing harmful materials home to families. Studies from NIOSH have shown three methods, as described below, to be effective at tracing lead contamination to family exposure. These techniques are cost effective for contractors to execute at the construction site with minimal disruption to production.

Piacitelli and Whelan (1996) recommended sampling for lead dust on hands and automobiles to determine the effectiveness of a company's lead prevention plan. Several techniques are currently available for testing. One technique involves a wipe sampling method. The NIOSH wipe sampling method (9100) utilizes unmoistened or premoistened towelettes to wipe the test area (e.g. hands, automobile steering wheel, tools, lunch cooler) using the following procedure (Piacitelli et al., 1997).

1. Using a new pair of gloves, remove a gauze pad from its protective package. Moisten the gauze pad with approximately 1 to 2 mL of distilled water.

   NOTE 1: Apply no more distilled water than that necessary to moisten approximately the central 80% of the area of the gauze pad. Excess distilled water may cause sample loss due to dripping from the gauze pad.

   NOTE 2: If using the premoistened Wash'n Dri™, omit the distilled water.
2. Place the template over the area to be sampled. Wipe the surface to be sampled with firm pressure, using 3 to 4 vertical S-strokes. Fold the exposed side of the pad in and wipe the area with 3 to 4 horizontal S-strokes. Fold the pad once more and wipe the area with 3 to 4 vertical S-strokes.
3. Fold the pad, exposed side in, and place it in a new plastic bag. Seal and label the bag clearly. Discard the gloves.
4. Clean the template in preparation for the next wipe sample.
5. Include two blank pads (moistened and placed in bags) with each sample set (NIOSH, 1994, p. 1).

After sampling, the wipes are collected and taken to an American Industrial Hygiene Association (AIHA) accredited laboratory to determine the lead loading levels. Based on a study testing 37 construction workers, results indicate an important relationship between blood lead levels and the amount of lead on workers' hands (Piacitelli et al., 1997). This method has been effective at forecasting blood lead levels in children (Lanphear, et al., 1995; Rabinowitz, Leviton, Needleman, Bellinger, Waternaux, 1985).

A second technique is the microvacuum method (Piacitelli et al., 1997). This method utilizes a personal sampling pump to collect dust on a filter, and the samples are again taken to an accredited AIHA laboratory/testing center. The filter is used to calculate the lead loading and the lead concentration (Piacitelli et al., 1997). The "lead concentration is therefore considered a measure of the potential lead hazard whereas the lead loading represents the immediate lead hazard" (Piacitelli et al., 1997, p. 448). Both methods have been effective at forecasting blood lead levels in children (Bornschein et al., 1985; Lanphear et al., 1995; Rabinowitz et al., 1985).

The final, and most cost friendly, technique is the *Handwipe Disclosing Method for the Presence of Lead*, designed and patented in 2001 by NIOSH (Sofge, 2003). This method is a qualitative technique created to detect the existence or nonexistence of lead on a person's skin and surfaces (Sofge, 2003). According to Ashley (2009), the steps for completing this test are as follows:

1. Read the instructions provided in the kit.
2. Prepare the lead indicator solution.
3. Wipe hands or surface to be sampled for 30 seconds (using ASTM E1792 wipes).
4. Spray three pumps of extraction solution (solution #1) onto center of wipe.
5. Spray two to three pumps of the disclosing solution (bottle #2) onto the center of the wipe.
6. The existence of lead is revealed if the wipe turns a pink to red color. Conversely, the absence of lead is disclosed if the wipe turns a yellow color (slides 7-13).

The results, acquired through sampling, will potentially identify flaws in existing hygiene procedures and a need to enforce safety protocols to minimize the potential for carrying hazardous chemicals and substances home.

Conclusion

The purpose of the review of literature is to examine available information and pertinent studies that relate to construction worker transportation of hazardous substances home as well as the potential family health effects from exposure. As a result, the information collected from the literature review provides an outline of best practices to minimize exposure to workers and their families. The literature review also provided elements on how a company is able to sample for lead, mercury, and benzo(a)pyrene. The next chapter includes the methodology in which the study was conducted.

Chapter III: Methodology

Research indicates that families of workers are continuing to be exposed to hazardous substances in the construction industry. Identifying best practices in order to minimize potential exposure is integral to eliminating the source of contamination in the homes of construction workers. The purpose of this study was to investigate possible exposure of workers to soils contaminated with lead, mercury, and benzo(a)pyrene, while constructing the urban reconstruction project, and develop a plan to reduce or prevent second-hand exposure to these toxic substances from the site. The study intends to analyze potential harmful levels of lead, mercury, and benzo(a)pyrene in the soil where workers performed construction activities and to publish procedures to assist contractors, in the construction community, in identifying and controlling these hazards. In order to accomplish this purpose, four research questions were developed as follows:

1. What levels of lead, mercury, and benzo(a)pyrene were present in the soil where workers performed construction activities on a specific urban reconstruction project?
2. How did the measured concentrations of lead, mercury, and benzo(a)pyrene in soil samples compare to acceptable levels as defined by the Minnesota Pollution Control Agency's standard for short-term exposure?
3. What are the possible physiological effects of lead, mercury, and benzo(a)pyrene contaminants on the workers and their families?
4. What preventative measures should occur in order to minimize the transport of toxic materials home from a construction site and, thus, curtailing exposure to a person's household?

This chapter describes the subject selection and description, data collection procedures, data analysis, and limitations of the study.

Sample Selection and Description

The sample for the research questions did not involve human subjects or data about human subjects. The sample was derived from documentation from an urban reconstruction project and findings in the literature review concerning physiological effects from exposure to lead, mercury, and benzo(a)pyrene as well as industry best practices regarding the prevention of transporting contaminants home to workers' families.

Data Collection

The data source, used to achieve research questions one and two, was acquired through the project's owner and prepared by Soil Testing Company XYZ. The information contained within the report was recorded and maintained by the project's owner within the environmental remediation section. The geotechnical report contains a summary of soil testing results from specific locations throughout the project's corridor. This data includes sample location, soil contaminants (benzo(a)pyrene, lead, mercury, etc.), and measured concentration (milligrams per kilogram) of each identified contaminant in the soil sample. The urban reconstruction project owner provided the researcher with Soil Testing Company XYZ's report containing the above aforementioned information, which may identify the potential for take-home contaminates by the construction workers.

The data source, used to achieve research questions three and four, was findings from the literature review concerning physiological effects from exposure to lead, mercury, and benzo(a)pyrene as well as industry best practices regarding preventing the transportation of contaminants home to workers' families. Additionally, three contractors' safety plans were obtained from the project's owner. These manuals contain specific information pertaining to each company's safe work practices and procedures that governed the work performed on the urban reconstruction project.

Data Analysis

Data, associated with research questions one and two, was analyzed to ascertain the potential for a worker's exposure to lead, mercury, and benzo(a)pyrene in the soil while constructing the urban reconstruction project. This information was compared to the MPCA's Short-Term Worker Soil Reference Values (SRVs) (MPCA, 2009). Specifically, Table 3 outlines the 16 examined locations and associated contaminants sampled. The data analysis was performed using an Excel spreadsheet.

Table 3

Locations Analyzed in Review of Soil Testing Data

Location	Contaminant
Area 1-2	Benzo(a)pyrene [B(a)P]
	Mercury
	Lead
Area 3-1	B(a)P
	Lead
Area 3-4	B(a)P
Area 3-6	B(a)P
Area 5A-3	Lead
Area 9-1	Mercury
Area 9-3	Mercury
Area 9-4	Mercury
Area 10-4	Mercury
CC01	Lead
CC03	B(a)P

CC05	Lead
CC07	B(a)P
CC09	B(a)P
CC11	B(a)P
OMF	B(a)P
	Lead

In order to address research question number three, data from the literature review of physiological effects from exposure to lead, mercury, and benzo(a)pyrene was summarized and divided into three categories: 1) blood lead levels and associated health effects; 2) acute and chronic ramifications linked to mercury exposure; 3) short-term and long-term effects connected to benzo(a)pyrene exposure.

Data analyzed for research question number four was accomplished by performing an analysis between the three contractors' safety plans and comparing these plans with what the review of literature demonstrated to be best practice for not contaminating families of workers as it relates to the development of prevention measures (see Table 4).

Table 4

Best Industry Practices for Preventing Take-Home Contamination

Component	Best Practices
Engineering Controls	Ventilation
	Wetting
	Vacuum
Personal Protective Equipment (PPE)	Protective clothing
	Protective gloves
	Respirator
Warning Signs	Post warning signs around lead contaminated work areas

Personal Hygiene	Hand washing facility
	No eating or drinking in contaminated area
	Shower before leaving work
	Change into work clothes at jobsite
	Place clothing to be worn home in a contaminant free space
	Employer laundering of work clothes
	Launder work clothes separately from family laundry at home
Medical Surveillance	Monitor the blood lead levels (BLLs) in workers
Training	Use and maintenance of personal protective equipment
	Personal hygiene
	Safe work procedures
	Material safety data sheets
	Potential adverse health effects
	Early detection of lead intoxication
	Risk to family members from home contamination and ways to prevent it
	Avoid visitors at the jobsite
	Prohibit taking toxic substances or contaminated items home

Limitations

This study has a number of limitations. They have been identified as follows:

1. The focus of this study was on the urban reconstruction project in Minnesota.
2. This study is limited to workers' exposure to toxic substances on the construction site and within the project limits.

3. A survey of construction workers was not conducted due to the seasonal nature of the industry.
4. The data was limited by the accuracy of the soil collection methods and the chemical measurements in each sample from the Soil Testing Company XYZ.
5. The results are limited to the researcher’s knowledge, education, and accuracy of the data collected by the state agency.
6. The review of the contractors’ safety plans is limited to information contained within each company’s manual. No training documents were evaluated.

Chapter IV: Results

The purpose of this study was to investigate the potential exposure of workers to contaminated soils while constructing the urban reconstruction project as well as to develop a plan to reduce or prevent second-hand exposure to these toxic substances from the site. The study intended to analyze the potential harmful levels of lead, mercury, and benzo(a)pyrene in the soil where workers performed construction activities and to publish procedures to assist contractors, in the construction community, to identify and control these hazards. In order to accomplish this purpose, four research questions were developed as follows:

1. What levels of lead, mercury, and benzo(a)pyrene were present in the soil where workers performed construction activities on the urban reconstruction project?
2. How did the measured concentrations of lead, mercury, and benzo(a)pyrene in soil samples compare to acceptable levels as defined by the Minnesota Pollution Control Agency's standard for short-term exposure?
3. What are the possible physiological effects of lead, mercury, and benzo(a)pyrene contaminants on the workers and their families?
4. What preventative measures should occur in order to minimize the transport of toxic materials home from a construction site and, thus, curtailing exposure to a person's household?

The methodology used to answer the research questions included data analysis conducted on measured contaminants' concentrations reported by Soil Testing Company XYZ. These concentrations were compared to MPCA's Short-Term SRV for each contaminant; an analysis was then performed on the three contractors' safety plans compared to what the review of literature demonstrated to be best industry practices.

Presentation of Data Collected

Data presented in this chapter is based on the four research questions. The first research question (RQ) asked what levels of lead, mercury, and benzo(a)pyrene were present in the soil where workers performed construction activities on the urban reconstruction project. This question is answered in one section (RQ 1.1). Question number two asked how do the measured concentrations of lead, mercury, and benzo(a)pyrene in soil samples compare to acceptable levels as defined by the MPCA's standard for short-term exposure. The response is presented in two sections (RQ 2.1–2.2). Question number three asked what were the possible physiological effects of lead, mercury, and benzo(a)pyrene contaminants on the workers and their families. The answer is summarized in four sections (RQ 3.1–3.4). The fourth research question addressed what preventative measures should be taken to minimize transporting toxic materials home from a construction site and, thus, curtailing exposure to a person's household. The response is detailed in one section (RQ 4.1) through a comparison of three contractors' safety plans to industry best practices for prevention measures. Each section includes a synopsis of the research results followed by the specific information for each research question configured into a table.

Research question number one: what levels of lead, mercury, and benzo(a)pyrene were present in the soil where workers performed construction activities on the urban reconstruction project? The soil testing company confirmed a detectable amount of lead, mercury, and benzo(a)pyrene at 16 sites within the project's work limits. Lead was found in the soil at six locations, mercury at five locations, and benzo(a)pyrene at nine locations. The concentrations measured for each material are detailed in Table 5.

Table 5

RQ 1.1: Location and Measured Concentration for Each Contaminant

Location	Contaminant	Measured Concentration (mg/kg)
Area 1-2	B(a)P	70.36
	Mercury	0.48
	Lead	360
Area 3-1	B(a)P	79.65
	Lead	1000
Area 3-4	B(a)P	18.96
Area 3-6	B(a)P	16.78
Area 5A-3	Lead	730
Area 9-1	Mercury	7.4
Area 9-3	Mercury	0.56
Area 9-4	Mercury	10
Area 10-4	Mercury	0.73
CC01	Lead	320
CC03	B(a)P	3.82
CC05	Lead	730
CC07	B(a)P	3.97
CC09	B(a)P	11.67
CC11	B(a)P	2.51
OMF	B(a)P	6.12
	Lead	9500

Research question number two: how did the measured concentrations of lead, mercury, and benzo(a)pyrene in soil samples compare to acceptable levels as defined by the Minnesota Pollution Control Agency's standard for short-term exposure? Table 6 depicts the concentration of each contaminant in the soil at each of the 16 locations and the associated SRV as determined by the MPCA. As portrayed in Table 7, 10 of the 16 sites, with measurable levels of lead, mercury, and benzo(a)pyrene, were identified as exceeding the MPCA's recommended levels for short-term worker exposure. Significant concentrations were detected at five locations. Area 1-2 tested positive for benzo(a)pyrene at a concentration five times the acceptable level. Similarly, Area 3-1 measured a concentration nearly eight times the acceptable level. The soil concentrations of mercury in Areas 9-1 and 9-4 were 18 and 25 times, respectively, the recommended level. Finally, soil lead level at OMF was over 13 times the MPCA's SRV. Chapter V will present conclusions based on this data analysis.

Table 6

RQ 2.1: Measured Concentration Compared to MPCA's Short-Term SRVs

Location	Contaminant	Measured Concentration (mg/kg)	MPCA Short-Term SRV (mg/kg)
Area 1-2	B(a)P	70.36	14
	Mercury	0.48	0.4
	Lead	360	700
Area 3-1	B(a)P	79.65	10
	Lead	1000	700
Area 3-4	B(a)P	18.96	14
Area 3-6	B(a)P	16.78	14
Area 5A-3	Lead	730	700
Area 9-1	Mercury	7.4	0.4
Area 9-3	Mercury	0.56	0.4
Area 9-4	Mercury	10	0.4
Area 10-4	Mercury	0.73	0.4
CC01	Lead	320	700
CC03	B(a)P	3.82	14
CC05	Lead	730	700
CC07	B(a)P	3.97	14
CC09	B(a)P	11.67	14

CC11	B(a)P	2.51	14
OMF	B(a)P	6.12	14
	Lead	9500	700

(MPCA, 2009)

Table 7

RQ 2.2: Summary of Soil Samples Exceeding MPCA's Short-Term SRVs

Location	Contaminant	Measured Concentration (mg/kg)	MPCA Short-Term SRV (mg/kg)
Area 1-2	B(a)P	70.36	14
Area 3-1	B(a)P	79.65	10
	Lead	1000	700
Area 3-4	B(a)P	18.96	14
Area 3-6	B(a)P	16.78	14
Area 5A-3	Lead	730	700
Area 9-1	Mercury	7.4	0.4
Area 9-4	Mercury	10	0.4
Area 10-4	Mercury	0.73	0.4
CC05	Lead	730	700
OMF	Lead	9500	700

(MPCA, 2009)

Research question number three: what are the possible physiological effects of lead, mercury, and benzo(a)pyrene contaminants on the workers and their families? The literature review provided specific side effects for each of the toxins. This information is summarized in three tables. Table 8 details the approximate blood lead levels measured in adults and children and the associated health effects at those levels. The research data shown in Table 9 and Table 10 is divided into two physiological effects, short-term and long-term, for mercury and benzo(a)pyrene, respectively.

Table 8

RQ 3.1: Blood Lead Levels and Health Effects in Adults

Severity	Adult BLL (µg/dL)	Potential Health Effect
Normal	<10	None Reported
Elevated	>25	Hypertension
		Reduced auditory ability
		Numbness
		Muscle and joint pain
		Potential reproductive issues
Serious	>40	Exhaustion
		Headaches
		Reduced blood cell creation
Severe	>80	Anemia
		Renal failure
		Death

(ASTDR, 2010; Swartz, 2001; L&I WA, 2000)

Table 9

RQ 3.2: Blood Lead Levels and Health Effects in Children (<6 years old)

Severity	Child BLL (µg/dL)	Potential Health Effect
Normal	≤5	Unknown
Elevated	>5	Reduced IQ
		Learning disabilities
		Attention deficit hyperactivity disorder
		Poor problem solving skills
	>45	Neurological issues
		Anemia
	>70	Cognitive disabilities
		Growth retardation
		Coma
		Death

(ASTDR, 2012; Bellinger, 2008; Godwin, 2009; NSC, 2009)

Table 10

RQ3.3: Workplace Mercury Exposure and Human Health Effects

Element	Short-Term Effects	Long-Term Effects
Metallic Mercury	Tremors Emotional changes Insomnia Muscle weakness Headaches Reduced motor and cognitive function	Respiratory Cardiovascular Gastrointestinal
Inorganic Mercury	Renal damage Gastrointestinal disorders Skin rashes Lack of muscle strength	Renal tubule disorder Renal filtering disorder Pink disease Peripheral nervous system disorders

(ATSDR, 1999; EPA, 2012; WHO, 2009)

Table 11

RQ 3.4: Workplace Benzo(a)pyrene Exposure and Human Health Effects

Short-Term Effects	Long-Term Effects
Pulmonary complications	Bronchitis
Gastritis	Persistent cough
Cognitive changes	Skin sensitivity to sunlight
Headaches	Pilosebaceous reactions
Leukemia	Leukemia
Lymphoma	Lymphoma
Renal cancer	Renal cancer
Bladder cancer	Bladder cancer

(ASTDR, 1995)

Research question number four: what preventative measures should occur in order to minimize the transport of toxic materials home from a construction site and, thus, curtailing exposure to a person's household? In a review of the three current site specific safety plans, Company A's safety and health plan (dated January 12, 2011) included 10 of the 24 elements identified as industry best practices in the literature review (see Table 8), Company B's safety and health plan (dated July 13, 2011) included 11 of the 24 components, and Company

C's safety and health plan (dated December 1, 2010) included 18 of the 24 elements. Each of the safety plans was very generic and preventative measures were only briefly covered in the specific policy.

With regards to Company A and Company B, the 13 to 14 best practice components were omitted from their respective safety manuals. The omitted components would typically fall into the categories of personal hygiene, medical surveillance, and training. As Table 8 indicates, Company A and Company B did not utilize a majority of the best practices to prevent transporting contaminants home and potentially exposing family members. Company C was deficient in the personal hygiene and training aspects of its safety plan. Company C, however, was the only contractor to, specifically, address lead decontamination procedures. Chapter V will provide conclusions regarding this data, and make recommendations to assist contractors, in the construction community, to identify and control these hazards by employing industry best practices.

Table 12

RQ 4.1: Contractor Safety Plans Compared to Best Industry Practices

Component	Best Practices	Company A	Company B	Company C
Engineering Controls	Ventilation	Yes	Yes	Yes
	Wetting	Yes	Yes	Yes
	Vacuum	No	No	Yes
PPE	Protective clothing	Yes	Yes	Yes
	Protective gloves	Yes	Yes	Yes
	Respirator	Yes	Yes	Yes
Warning Signs	Post warning signs around lead contaminated work areas	Yes	Yes	Yes
Personal Hygiene	Hand washing facility	No	Yes	Yes
	No eating or drinking in contaminated area	No	No	Yes
	Shower before leaving work	No	No	Yes
	Change into work clothes at	No	No	Yes

	jobsite			
	Place clothing to be worn home in a contaminant free space	No	No	No
	Employer laundering of work clothes	No	No	No
	Launder work clothes separately from family laundry at home	No	No	No
Medical Surveillance	Monitor the blood lead levels (BLLs) in workers	No	No	Yes
Training	Use and maintenance of PPE	Yes	Yes	Yes
	Personal hygiene	No	No	Yes
	Safe work procedures	Yes	Yes	Yes
	Material safety data sheets	Yes	Yes	Yes
	Potential adverse health effects	Yes	Yes	Yes
	Early detection of lead intoxication	No	No	No
	Risk to family members from home contamination and ways to prevent it	No	No	No
	Avoid visitors at the jobsite	No	No	No
	Prohibit taking toxic substances or contaminated items home	No	No	Yes

Chapter V: Discussion

Research indicates that families of workers are continuing to be exposed to hazardous substances in the construction industry. Identifying the best practices in order to minimize potential exposure is integral to eliminating the source of contamination in the homes of construction workers. The purpose of this study was to investigate the potential exposure of workers to soils contaminated with lead, mercury, and benzo(a)pyrene while constructing the urban reconstruction project and develop a plan to reduce or prevent second-hand exposure to these toxic substances from the site. The study intended to analyze the potential harmful levels of lead, mercury, and benzo(a)pyrene in the soil where workers are performing construction activities and to publish procedures to assist contractors, in the construction community, to identify and control these hazards. In order to accomplish this purpose, four research questions were developed as follows:

1. What levels of lead, mercury, and benzo(a)pyrene were present in the soil where workers performed construction activities on a specific urban reconstruction project?
2. How did the measured concentrations of lead, mercury, and benzo(a)pyrene in soil samples compare to acceptable levels as defined by the Minnesota Pollution Control Agency's standard for short-term exposure?
3. What are the possible physiological effects of lead, mercury, and benzo(a)pyrene contaminants on the workers and their families?
4. What preventative measures should occur in order to minimize the transport of toxic materials home from a construction site and, thus, curtailing exposure to a person's household?

The methodology used to achieve the research objectives included a data analysis performed on the project's soil testing report compared to the MPCA's SRVs, an extensive literature search identifying the health effects associated with each toxin, and a gap analysis conducted on three contractors' safety plans as it related to preventing second-hand contamination compared to best industry practices described in literature. This chapter will present findings and conclusions, recommendations, and discuss suggestions where further studies are necessary.

Findings and Conclusions

Information presented is categorized in line with the four research questions. The most significant findings are listed below each research question and subsequent conclusions are shown based on the analyses.

Research question number one: what levels of lead, mercury, and benzo(a)pyrene were present in the soil where workers performed construction activities on the urban reconstruction project?

- Soil Testing Company XYZ's report indicated a measurable concentration of the contaminants at 16 locations within the project's work limits.
- Lead was found in the soil at six locations.
- Mercury was confirmed at five locations.
- Benzo(a)pyrene was verified at nine locations.

The results indicated that the potential for worker exposure to these toxins existed. The recommendations section, shown below, presents methods for minimizing the transportation of each contaminant home.

Research question number two: how did the measured concentrations of lead, mercury, and benzo(a)pyrene in soil samples compare to acceptable levels as defined by the Minnesota Pollution Control Agency's standard for short-term exposure?

- 10 of the 16 locations exceeded the MPCA's recommended SRV for each contaminant or combination of contaminants.
- The soil concentrations of benzo(a)pyrene in Areas 1-2 and 3-1 were five times and nearly eight times, respectively, the acceptable level.
- The soil concentrations of mercury in Areas 9-1 and 9-4 were 18 and 25 times, respectively, the recommended level.
- Soil lead level at OMF was more than 13 times the SRV.

When soil concentrations exceed the MPCA's SRV, it represents an at-risk condition. There was a high probability that workers were exposed to lead, mercury, and benzo(a)pyrene. Contractors should have implemented all necessary measures to prevent or minimize worker exposure and the possibility for the transportation of the toxin(s) home.

Research question number three: what are the possible physiological effects of lead, mercury, and benzo(a)pyrene contaminants on the workers and their families? The data presented in the Chapter IV regarding health effects from exposure to these toxins was based on other industries. The review of literature identified a knowledge gap between a construction worker's exposure, as it relates to the concentration of lead, mercury, and benzo(a)pyrene in soil, and adverse health effects to workers and their families. One is able to conclude that the side effects due to exposure to these toxins represent a loss to the worker, the worker's family member(s), and the company. This translates into a loss of assets, such as people, time, currency, and legal for an organization.

Research question number four: what preventative measures should occur in order to minimize the transport of toxic materials home from a construction site and, thus, curtailing exposure to a person's household? The assessment performed, on research question number four, demonstrates that a majority of the contractors' safety plans were deficient in several vital elements that have been identified as best industry practices for not contaminating families.

- Company A's safety and health plan included 10 of the 24 elements identified as industry best practices in the literature review.
- Company B's safety and health plan included 11 of the 24 components.
- Company C's safety and health plan included 18 of the 24 elements.
- Company A and Company B omitted 13 and 14 best practice components in the categories of personal hygiene, medical surveillance, and training
- Company C was deficient in personal hygiene and training aspects of its safety plan.
- Company C was the only contractor to specifically address lead decontamination procedures.

It is evident that three contractors' safety plans did not compare positively to several of the best industry practices. This inconsistency may be a result of a lack of knowledge among occupational safety and health employees or plan writers for these construction companies. If the employees are aware of these best industry practices, the required updates may not be occurring due to a deficiency in top management support.

Recommendations

Implementation of the subsequent procedures would be beneficial to contractors, in the construction industry, in order to identify and control a worker's contact with contaminated soils and, thus, preventing transportation of harmful toxins home and exposing family members.

- Determine the level of risk to your employees and subcontractors.
    - Do construction activities disturb the soil?
    - Does the project require personnel to be in contact with soil?
    - Is the project site a known hot spot?
        - Contact the local municipality or state government.
        - If not, contract with a soil testing company to sample for potential contaminants.
    - Do the concentrations of the identified contaminant exceed the MPCA's Soil Reference Value for acute worker exposure?
    - The risk level is low if the concentration of a contaminant is less than the MPCA's SRV (MPCA, 1999).
    - The risk level is high if the concentration of a contaminant is greater than the MPCA's SRV (MPCA, 1999).
- Are the necessary safety and health procedures in place?
    - The following is a list of resources for additional information.
        - OSHA General Duty Clause
        - OSHA 1926.62 Lead in Construction
        - NIOSH Workplace Safety and Health Topics
        - National Safety Council
        - The Associated General Contractors of America
        - Minnesota Pollution Control Agency

- Control measures to prevent or minimize exposure.

  1. Engineering

     - Provide local ventilation for enclosed areas.
     - Lightly wet the soil, if possible or practical.
     - Vacuum cleanup with a high-efficiency particulate air (HEPA) filter.

  2. Administrative

     - Place caution signs along the perimeter of contaminated construction zones.
     - Provide a hand washing and/or showering facility.
     - Provide employer laundering of protective work clothes.
     - Monitor the blood lead levels of your employees.
     - Train personnel in the following areas:
       - Use and maintenance of personal protective equipment.
       - Proper individual hygiene.
         - Wash hands prior to eating and leaving the work area.
         - No consumption of food or beverages in contaminated work zone(s).
         - Change into work clothes at jobsite.
         - Place clothing to be worn home in a contaminant free space.
         - Launder work attire separately from family laundry at home.
       - Safe work procedures.
       - Material safety data sheets.
       - Possible physical consequences from exposure.
       - Early detection of lead poisoning.

- Risks to family members from transporting contaminants home and ways to prevent it.
- Avoid visitors at the jobsite.
- Prevent removing contaminated items (e.g. tool, equipment, etc.) for the job.

3. Provide necessary personal protective equipment.
    - Protective clothing
    - Protective gloves
    - Respirator

Recommendations for Further Research

It is recommended that studies be conducted that examine a construction worker's exposure to lead, mercury, and benzo(a)pyrene contaminated soils and the potential health effects to family members at home. If study is to be performed in the future regarding take-home contaminates, the researcher also recommends conducting a survey of the construction workers and occupational safety and health personnel to determine their comprehension. Further training regarding techniques to prevent carrying toxins home and exposing relatives is recommended as well.

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