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Human Health Risk Assessment of Trace Metals in Indoor Dust.

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HUMAN HEALTH RISK ASSESSMENT OF TRACE METALS IN INDOOR DUST

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Associate Professor Hyun-Min Hwang, Ph.D., Advisor

The risk associated with exposure to heavy metals found in indoor dust is viewed as a serious hazard to human health, and heavy metal pollution of the environment is a major concern on a global scale. Accordingly, the current study set out to assess the heavy metals concentrations in indoor dust and the hazards they bring in adults and children. 71 indoor dust samples were collected from wooden flooring and analyzed using ICP-MS apparatus. Comparing our findings to the Environmental Protection Agency's acceptable risk criteria showed that lead (Pb), manganese (Mn), Chromium (Cr), copper (Cu), and zinc (Zn) had high absorbed daily dosages in both children and adults. The median CR values for Pb indicated a significant probability of developing cancer. As a result of the non-bioaccumulation nature of trace metals in the body, the mean values of CR for the remaining elements were lower risk in both children and adults and have not exceeded the permissible limit set by USEPA, suggesting that these metals may not pose a future non-carcinogenic or carcinogenic risk to humans. We conclude that if the home's location wasn't carefully considered, heavy metal exposure could increase health risks. Following the findings, we recommend more comprehensive and adequate measures should be made to reduce the impacts and cancer risk associated with indoor floor dust ingestion in both

children and adults. Adults should be informed of associated risks to safeguard their health and children health.

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LIST OF ABBREVIATIONS

Al	Aluminum
AT	Average exposure Time
ADD	Absorbed Daily Dosage
As	Arsenic
BGS	British Geological Survey
BW	Body Weight
Cd	Cadmium
CF	Conversion Factor
CNS	Central Nervous System
Co	Cobalt
Cr	Chromium
CRs	Carcinogenic Risks
Cu	Copper
ED	Duration of Exposure
EF	Exposure Frequency
EN	European Standard (Norm)
EPA	Environmental Protection Agency
Fe	Iron
FM	Flame Retardant
Hg	Mercury
HI	Hazard Index

HQ Hazard Quotient

HRA Health Risk Assessment

HVS3 High Volume Small Surface Sampler

IARC International Agency for Research on Cancer

ICP-MS Inductively Coupled Plasma Mass Spectrometry

IgR Rate of Ingestion

LADD Lifetime Absorbed Daily Dosage

Li Lithium

LCR Life Cancer Risk

Mn Manganese

Ni Nickel

Pb Lead

PBET Physiologically Based Extraction Test

PBDEs Polybrominated Diphenyl Ethers

RfD Reference Dose

RTV Room Temperature Vulcanization

SF Slope Factor

SHD Settled House Dust

Sn Antimon

UV Ultraviolet

VF Volatilization Factor

WHO World Health Organization

Zn Zinc

VITA

2015 ……..………………………………………………	B.S. Biology College of Applied Science Umm Al-Qura University
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I pray to Allah to make this work a useful science that will benefit me in this life and the hereafter. Without Allah, I could have never been able to achieve such a result.

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CHAPTER 1

INTRODUCTION

Nowadays, Human exposure to indoor contaminants became an emerging area of human concern. Humans spend the greatest part of their time indoors in houses, universities, and workplaces (Klepeis et al., 2001; Sharpe, 2004; Tran et al., 2012). Therefore, the quality of indoor environment is highly important when consider its impact on human health. The home environment can be a source of exposure to environmental contaminants such as persistent organic contaminants, trace metals, allergens, and tobacco smoke. Indoor dusts are solid particles ranging in size from 1-100 µm, which may be airborne depending on their origin, physical characteristics, and ambient conditions (Turner, 2011). Indoor dust can act as a medium for contaminants like toxic heavy metals (Whitehead et al., 2011).

Dust originates from a range of indoor and outdoor sources, including soil, pesticide, asbestos, pollen, bacteria, shed skin, smoke, and dust mites Moreover, Paints are a major wellspring of trace metals. For example, yellow paint has been linked to the high concentrations of zinc (Zn), copper, lead, and cadmium (Cd) in indoor dust (Chattopadhyay et al., 2003). External or outside sources include roadside dust, soil, vehicles, and industrial particulates are also an important source of heavy metals and trace elements present in the dust (Chattopadhyay et al., 2003; Khoder et al., 2010; Charlesworth et al., 2011).

Various studies monitored the presence of heavy metals and toxic trace elements in indoor dust (Lu et al., 2009). So detailed characterization of dust composition is required to identify its potential impacts on human health. Heavy metals are considered as one of the most critical contaminants in indoor dust. Heavy metals have the potential to accumulate in human tissues causing nervous system disorders, kidney dysfunction, immune system dysfunctions, and vascular damage due to their bioaccumulation. They are defined as metallic elements that have a relatively high density and are toxic. Some metals such as arsenic, lead, cadmium, and titanium are toxic even in trace amounts. Heavy metals can reach to indoor dust via various sources. Figure 1

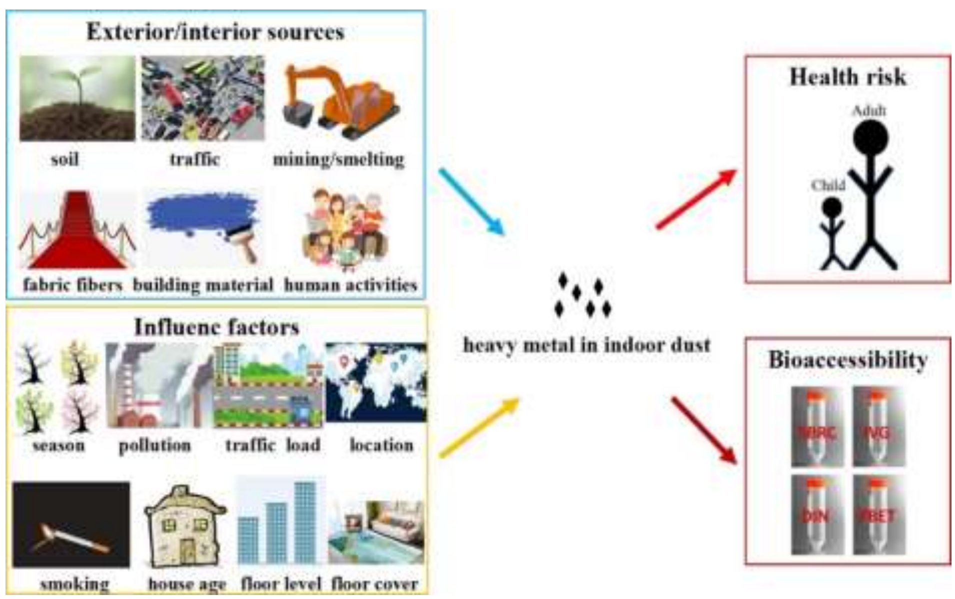

Figure 1: Representation of various sources of heavy metals in soil (Shi et al., 2021)

Trace Metal Exposure Pathways

Trace metals of indoor dust can mainly enter the human body through three exposure routes: ingestion, inhalation, and skin contact (Morawska et al., 2006). Metal ingestion can occur involuntarily with food and drink. Young children often ingest dust by regularly putting non-food items and their dirty hands in their mouths (Butte & Heinzow, 2002). Airborne dust particles provide significant health concerns when inhaled, including respiratory sickness, impaired lung function, and cardiovascular illnesses (Turner et al., 2010). Humans can also be exposed to heavy metals through dermal contact. For instance, nickel has been classified as a skin sensitizer that can cause allergic contact dermatitis, which can further lead to skin cancer depending upon the duration of exposure (Mazinanian et al., 2013).

Effect of Trace Metals on Health

The removal of trace metals has been a major concern recently due to their non-biodegradable and carcinogenic nature. These metals accumulate in the body of living organisms and pose a major health risk. (Gündoğan et al., 2004). The World Health Organization WHO has compiled a list of the top 10 dangerous compounds that represent a major threat to living beings' health because of air pollution. Most of these chemicals include heavy trace metals, which are mercury (Hg), arsenic (As), copper (Cu), excess fluoride, lead (Pb), and Cd (WHO, 2010). Furthermore, Zn and Cu perform some biological functions at concentrations that are low; however, at high concentrations, they are known to produce toxic effects (Bánfalvi, 2011). Other trace metals such as Ca, Cd, Pb, and Hg do not perform any physiological function in the body of living organisms. Therefore, very low concentrations of these elements can be very toxic, leading to serious health issues like cancer (Willers et al., 2005).

As indoor dust can accumulate persistent environmental contaminants over extended time periods, it has potential to be used for retrospective exposure assessment. Moreover, because indoor dust sampling is less invasive than collecting biological samples, such as blood (Whitehead et al., 2011), it can be used as a proxy for estimating human exposures for contaminants in indoor environments.

Study Objective

The main objectives of this study are as follows:

- To assess human health risks of trace metals that associated with exposure to indoor dust.
- To determine non-cancer risk and cancer risks of trace elements with the aid of Absorbed Daily Dosage (ADD) and Lifetime Absorbed Daily Dosage (LADD).
- To determine metal uptake rates and limits for children and adults via ingestion pathway.

Research Methodology

One of the great risks to human wellbeing is the profound metal affirmation that has been surveyed using mathematical assessments in past research, leading to the US EPA, for human wellbeing hazard evaluation and risk assessment. The US EPA human health risk assessment method will be adopted in this study. The US EPA model (2002) was designed to assess the nature and probability of adverse health effects on humans who may be exposed to trace metals in the environment. This same approach has been used in this research. The US EPA model is designed to address the likely adverse health outcomes from exposure, the probabilities of people experiencing the adverse health effects, and whether the current exposure levels pose a health risk to humans (US EPA, 2002).

CHAPTER 2

LITERARY REVIEW

In the past, indoor dust exhibited the least interest of research community. There were a few studies that described the composition of dust and the impact of different dust components on the individual's health. Recently, Covid -19 pandemic forced many peoples to home style office work, that in turn increased human indoor hours and increased human exposure to indoor dust. Studies analyzed indoor dust indicated the presence of several heavy metals that are toxic to human health. Heavy metals cause various diseases that can lead to death (Tran et al., 2020).

Fine powder (100 m) that can be found on the ground, on the surface of objects, or blown around by natural or mechanical forces is what we call "dust". Pollutants such as heavy metals are stored in the dust that accumulates indoors, which is a mixture of particles from both outside and inside the building. Since most individuals spend so much time inside, it's of growing worry that they might be ingesting or inhaling indoor dust (Yang et al., 2015).

People now spend the majority of their time indoors, therefore this topic has attracted a lot of attention from researchers and policymakers (Mitchell et al., 2007). A large number of studies (Olujimi et al., 2015) indicated that indoor dust could serve as a sponge for many contaminants, including heavy metals.

Dust and other pollutants, especially harmful heavy metals, can be brought indoors through infiltration of external pollutants and/or vehicle emissions, as well as by incense burning, smoking, furniture, building material, and occupants' activities. Emissions of pollutants, such as potentially harmful metals in the air environment, are a threat to public health today (Rashed, 2008).

One of the major routes through which people are exposed to hazardous heavy metals is through the dust they breathe or ingestion at home. Therefore, the study of indoor dust is an important way of determining the origin, distribution, and level of heavy metals because humans spend a great extent of their time in an indoor environment and metals in the indoor dust can accumulate in humans through inhalation, ingestion, or dermal contact absorption (Sabzevari & Sobhanardakani, 2018).

Given that young child, especially toddlers, spend the vast majority of their time indoors, and that they often eat food that has been handled by their bare hands or play with toys that have been handled by their bare hands, it stands to reason that indoor dust contamination is essential (Darus et al., 2012).

Assessing the Risk

The International Agency for Research on Cancer (IARC) has declared Chromium (Cr), Cd, Pb, and Arsenic (As) as carcinogens while declaring other metals, including Zinc (Zn), Iron (Fe), Cobalt (Co), and Cu as non-carcinogens. Metals Cd, As, Cr, and Pb are not being used because they are highly toxic and cause very dangerous pollution. A Health Risk Assessment (HRA) is a model that estimates the effects of contaminants and the risks on human health. The HRA consists of four parts: identification of hazard, assessment of exposure, evaluation of dose response, and characterization of risk. Hazard identification can be conducted via the compilation of data from previous studies. The data from these studies can be utilized to analyze the effects of trace elements on human health. Exposure evaluation relates to the transmission of heavy metals from the source, point of exposure, and receptor.

Due to their toxicity, longevity, and inability to biodegrade, heavy metals have long been recognized as major environmental contaminants. As and Pb concentrations in house dust, for instance, could have serious effects on human health. The acute toxicity of as is demonstrated by the fact that even moderate doses can disrupt the circulatory and nervous systems. Lead is toxic because it interferes with enzyme reactions and causes harm to the central nervous system. Other chemical components besides heavy metals can also be harmful to human health. For example, children's healthy growth and development rely on nutrients like P. Although the P exposure pathway was not fully established, patients with phosphorism were detected in an epidemiological investigation of locals living near a phosphate mine (Li et al., 2014).

Inhalation, dust ingestion, and skin contact are major routes of entry for heavy metals (Zheng et al., 2013). Children have been shown to absorb significant amounts of heavy metals from polluted dust through the hand-mouth route and another exposure route. Pb, Cd, Hg, Zn, and Cr are only a few of the heavy metals that have been linked to a host of health problems, including those of the neurological system, heart, blood, and bones, kidneys, mouth, and tremors. As a result, research on the prevalence of heavy metals indoors and the threats they pose to human health is essential (Shi.et al., 2011).

Heavy metals and metalloids like As, Pb, Cd, Cr, and Hg (henceforth referred to as trace metals), semivolatile and nonvolatile pesticides, plastic additives, flame retardants, and persistent organic pollutants like polycyclic aromatic hydrocarbons and polychlorinated biphenyls are just some of the toxicants that may be encountered in the home (Huang et al., 2010).

The dose-response evaluation covers heavy metal exposure and the effect(s) on human health. In the last step of the risk characterization, all the data from the previous three steps are combined to quantify the risk that a human can face. The lifetime cancer LCR and Hazard Quotient HQ, respectively, represent carcinogenic and noncarcinogenic risks, with the values of these parameters indicating the risk to human health. Hassan et al. (2012) studied trace elements in interior dust. Study results revealed that the maximum mean concentration of Cu, Cr, Co, Pb, nickel (Ni), and Cd were found in the entryways, stairs, and household dust. Moreover, internal sources and external sources are both instrumental in generating household dust as it is linked to the amount of metal in the home and the amount of dust in the doorway.

In addition, Olujimi et al. (2015) stated that children's primary route of exposure to hazardous metals is by ingestion of indoor dust because kids love to play on the floor and unwittingly consume the dust. Children may unwittingly eat dust that has clung to their skin. Last but not least, the wind-suspended dust could enter the kids' lungs through their noses and mouths (Latif et al., 2014).

Another study from Iran determined the health risk of trace elements from indoor and outdoor dust in various areas within the country. The concentrations of different trace metals were measured and reported. These concentration values were placed on par with the concentration values found in other parts of the globe (Fig 2). Four main trace metals were found in the dust sample which were Zn, Ni, Cd, and lead (Pd) (Ariapak et al., 2022)

Sample	Location	Element			
		Cd	Cr	Pb	Ni
Indoor dust	Iran	11.34	11.81	32.08	60.19
	China	-	94.60	8.40	-
	Saudi Arabia	-	-	23.0	-
	China	-	-	348.73	-
	Malaysia	-	-	31.24	-
	UK	1.95	84.30	-	43.40
	Malaysia	10.65	-	-	49.67
	UK	1.10	-	-	53.30
	Australia	2.0 - 2.50	104.0 - 202.0	-	27.0 - 49.0
	USA	-	-	-	23.6

Figure 2: Comparison of the trace element concentration in the indoor dust sample collected from Iran (Sabzevari & Sobhanardakani, 2018).

Researchers discovered that the heavy metals' hazard index was less than the one within the safe limits of the metals and the source of these metals in indoor dust was natural. Researchers who worked on the gastrointestinal tract of children (2-3-years) defined physiologically Based Extraction Test PBET as generating results for Pb and as bioavailability (with respect to monkeys, rats, and rabbits) in polluted soils (Sud et al., 2008). Some of the hazards of heavy metals such as arsenic and lead are presented in Figure 4.

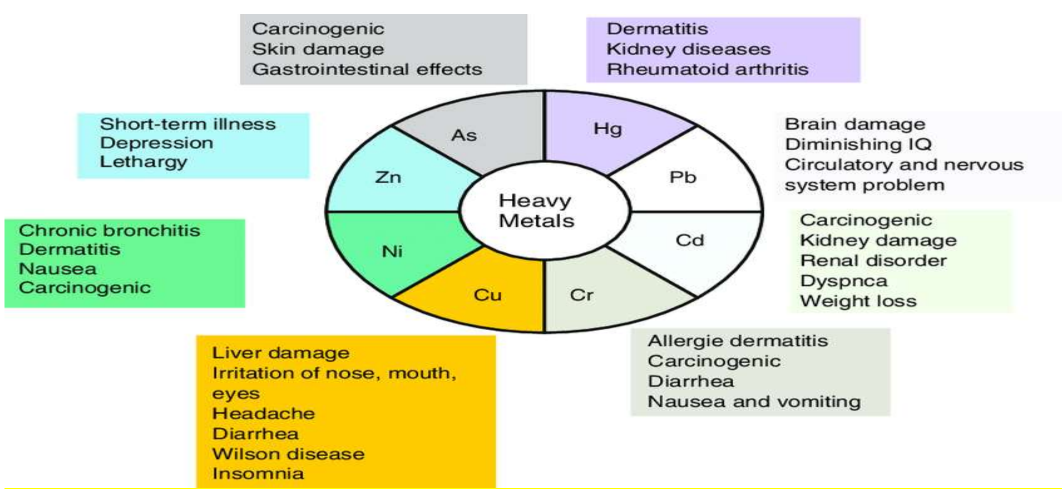

Figure 3: Hazards of heavy metals on human health (Sud et al., 2008).

Several physiologically based extraction test PBETs studies advocated in recent literature or by current regulatory agencies are based on a similarly broad model. These studies are differing in their accuracy when it comes to experimental and chemical circumstances, such as stomach phase pH, agitation means and speed, incubation period, and solid-fluid ratio (Denys et al., 2009; Stewart et al., 2003) These factors and their records in household dust have been identified since the 1970s on a much lower scale than in other heterogeneous solids. With neurotoxic predominance, there is a lack of data the bioavailability of these compounds (Demetriades et al., 2010; Kumar et al., 2009; Rasmussen et al., 2008; Turner & Ip, 2007; Breivik et al., 2002; Allen et al., 2008). The fraction of a chemical's total concentration that can be absorbed through a physiological membrane is referred to as bioavailability. An alternate, faster method of assessing bioavailability is to incubate samples of interest with chemical reagents that mimic the conditions found in the human lung or digestive region, followed by restricting the toxicants delivered into the aqueous phase through desorption, dissolution, and ion exchange processes. The quantity of a chemical compared to the overall amount that is soluble in the lung or gastrointestinal environment (which is not substantially available for further absorption) to the whole circulatory system is determined by in vitro approach (Turner & Ip, 2007).

Variation in Dust Samples

Researchers have compiled data on direct comparisons of contaminants assessed in vacuum sweeper dust and dust collected by a standardized process in the same dynasty (Breivik et al., 2002). In addition, they calculated the amount of Polybrominated Diphenyl Ethers (PBDEs) in normal dust and vacuum cleaner dust. PBDEs were common chemicals in the dust of two investigations. Results indicated that the concentration of PBDE was lower in home vacuum cleaner dust than in regular dust (Breivik et al., 2002; Colt et al., 2008). However, the researchers found that polycyclic aromatic hydrocarbons and polychlorinated biphenyls were extremely similar in 40 matched samples of High-Volume Small Surface HVS3-sampled and home vacuum cleaner dust, with the middle concentrations from both ways of collecting dust being similar (Colt et al., 2008; Harrad et al., 2008).

To back up this theory, researchers looked at levels in of PBDE in dust and biological samples (i.e., breast milk, plasma, and serum). They discovered a link between the PBDE levels found in household dust and the biological levels in individuals (Allen et al., 2008). They discovered a similar association in geographical regions with low and high PBDE levels in the dust. PBDE concentrations in household dust were positively connected with equivalent levels of PBDEs in breast milk and serum in the United States. Also, the same was seen for multiple levels of the reproductive hormone in serum (Wu et al., 2007). In a similar vein, two European investigations found significant associations between PBDE levels in dust and plasma (Frederiksen et al., 2010; Karlsson et al., 2007), while one Swedish study found a link between PBDE levels in dust and breast milk (Breivik et al., 2002).

Analysis of Indoor Dust

A study was conducted in Amman (Jordan) to determine the concentration of heavy metals in street dust, household dust, and garden soil samples. Results indicated that heavy metal concentrations of Ni, Cd, Zn, Cu, Pb, and Cr are higher in-house dust than in streets and gardens. The main cause of elevated Pb, Ni, and Zn in house dust was diesel oil or other furnaces (Al-Momani, 2007).

Other studies from Hong Kong and Ottawa (Canada) revealed various lethal effects of As on health, along with the effects of various metal ions. Arsenic is lethal for health and can cause cancer and skin lesions. Arsenic can also cause cardiovascular diseases and diabetes. Moreover, it negatively affects cognitive development in a child. Presence of pd in the human body can cause anemia, weakness, as well as kidney and brain damage. In addition, too much exposure can even result in death. pd can negatively effect on pregnant women by affecting the development of the unborn child's brain (Rasmussen et al., 2013; Hu et al., 2011).

Researchers analyzed different elemental forms of interior dust, exterior dust, and soil collected from 50 locations in 10 different zones of Ottawa. The study has revealed that the greatest amounts of Hg, Cd, and Pb have originated from indoor sources of household items. The consent action of these metals is higher in household dust than in garden and street dust. The total metal concentration may come from a biogenic source such as algae and fungi, which can increase the metal concentration to a high level (Rasmussen et al., 2008; Tong & Lam, 2000).

In Istanbul, Turkey, studies reported the presence of Mn, Cr, Ni, Cd, Pb, Zn, and Cu in household dust. Result revealed that there was no difference between office and household dust in Istanbul city. Researchers indicated that many factors can affect origin of heavy metals, such as pets, old buildings, wall paints, and the number of occupants. They observed that the number of occupants was the most significant factor responsible for the higher metal concentrations in household dust. The concentration of heavy metals in indoor dust is higher than in outdoor dust, as evidenced by the studies mentioned above. Building materials, age of structures, the number of residents, the type of heating, the neighborhood, particular personal interests, and ventilation behavior are all variables that contribute to elevated levels of trace metals in indoor dust (Kurt-Karakus, 2012; Kefeni, & Okonkwo, 2013).

Due to the vast amounts of time that people spend indoors (88% of the day for adults and 71-79% of the day for children), there has been rising worry over the years about their exposure to indoor toxins. Settled and re-suspended dust is a major contributor to indoor air pollution. Dust that has settled onto furniture, walls, floors, and carpets is a reservoir for pollutants. It is a complex mixture of organic and inorganic particles. Settled house dust can have a very different chemical make-up in different regions (particularly those with heavy industry or mining) and inside the walls of a single home (bedroom versus living room, etc) (Khoder et al., 2010).

Metals in the home's dust could originate from within the home or be tracked in from the outside. Soil and street dust adhere to inhabitants' shoes and dogs, bringing the contaminants inside homes. Between 30 and 40% of dust, loadings can be attributed to metals in the soil. Outside air containing dispersed particulate matter is another major entry point for metals into houses (Ibanez et al., 2010).

Contaminants in household dust can come from a wide variety of indoor sources, including but not limited to: cleaning supplies, paint chips, cooking fumes, cigarette smoke, building supplies, furniture, carpeting, emissions from heating systems, etc (Mcdonald et al., 2010).

Multiple studies have found elevated metal levels in house dust. However, few research has actually attempted to assess metal loadings, and even fewer have utilized a wipe sample method to evaluate the distribution of metal loadings between rooms (Rasmussen et al., 2013).

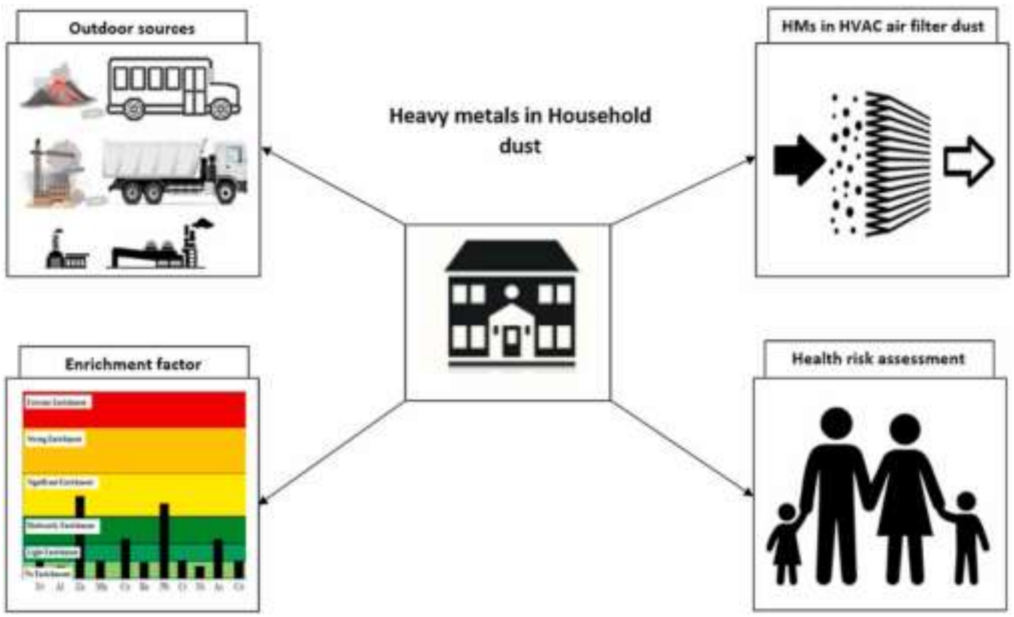

Figure 4: Heavy metals in household (Al-Harbi et al., 2021).

Exposure of Humans

According to researchers studying human exposure to main pollutants, Settled House Dust SHD could be a significant source of indoor contact (Lau et al., 1997). Many serious health effects have been related to indoor exposure to these pollutants, including the immune system and allergy effects, respiratory effects, cardiovascular and nervous system effects, irritating effects on mucous membranes and the skin, reproductive effects, and cancer (Mitra et al., 1995). Children who have a propensity for playing or crawling on the floor and putting items in close contact with dusty carpets or floors in their mouths may raise concerns about exposure to dust and its associated pollutant load (Moriske et al., 1996).

A complicated combination of biologically derived material (animal dander, fungus spores, etc)., particulate matter deposited from within the house, and soil particles moved in by foot traffic," according to a US EPA deposition from resuspension due to activities, airborne state, direct accumulation, and infiltration are all factors that influence indoor dust (Lewis et al., 1999). The precise configuration of a house dust sample is influenced by environmental and seasonal factors, air filtration and vacuuming, homeowner activities, and interior and exterior source activities. Research has found that indoor dust particles are formed by the diffusion of outside particles into the indoor environment. Fibers from furniture, clothing, hair, skin, mites, cigarette smoke, culinary emissions, and heating emissions are all sources of dust in the home (Rudel et al., 2001). Pollen, soil, volcanic debris, and emissions from forest fires are all-natural sources of dust particles in the environment. Anthropogenic sources of outdoor dust particles include waste incineration, fossil fuel combustion (e.g., oil, coal), wood combustion, and a variety of industrial processes (e.g., extraction of iron, construction) (Chuang, 1996). Differences in particle size, particle shape, composition, and contaminant concentration between indoor and outdoor harvests, caused a complex set of media that can be greatly altered in terms of spatial and temporal inconsistency. As a result, SHD configuration might vary drastically between rooms inside a house, as well as between houses and geographic areas within a study portion (Maertens et al., 2008).

Roberts & Dickey, (1995) investigated the correlations between the mutagenicity of dust samples and evidence gathered from homeowners. The age of the carpet and the

Salmonella mutagenicity scale with a metabolic beginning were shown to be statistically significant.

Heavy metal contamination of soils has negative effects on human health, especially in youngsters. Due to their active digestive systems, tiny body sizes, inadequate immune systems, and extensive use of hands, children have a very high rate of heavy metal absorption. Since the human body lacks a reliable system for naturally rejecting heavy metals, they can cause serious harm when ingested (Kurt-Karakus, 2012).

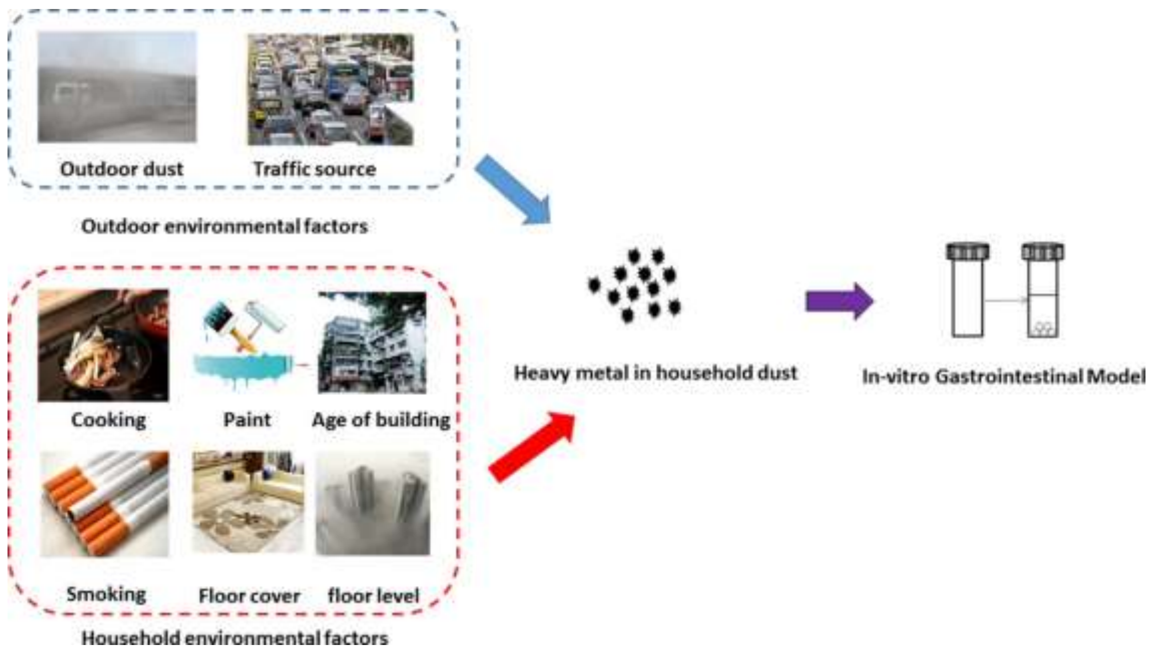

Figure 5: Incoming dust in houses from urban areas (Cheng et al., 2018).

Risk Associated with Children

Ruby et al. (1996) describe a PBET, which is based on the gastrointestinal tract of a (2 -3) year old child and records the effects of Pb and bioavailability (in rabbits, rats, and monkeys) in polluted soils. Many PBETs proposed in recent works or by current governing organizations were based on the same broad concept but differed in specific chemical and experimental parameters, such as the solid-to-liquid ratio, incubation period, stomach pH, and agitation mean and speed (Akhter et al., 1993; Stewart et al., 2003). Synthetic stomach fluids or PBETs have used in several investigations to determine the bioaccessibility of lead in home dust. Bioaccessibility in the stomach ranges from about 25 to 80 % but the resulting convenience in the intestinal tract is limited, presumably due to the reabsorption of the metal to changed dust particles or precipitation with phosphate (as chloropyromorphite; $Pb_5(PO4)_3Cl$) as the pH rises. Based on these observations, lead will tend to overvalue oral accessibility in domestic dust when during an imitation stomach phase (Harrison et al., 1979; Yu et al., 2006).

Despite the obvious and immediate effects on human health, awareness of the bioaccessibility of trace metals other than lead in household dust has recently developed. Researchers used an artificial stomach solution such as acidified pepsin to determine the conveniences of several trace metals in numerous household dust samples, while Rasmussen et al. (2008) used EN 71-3 (1994) to regulate the stomach availability of Zn, Ni, and Cu in house dust and associated garden soils (Turner & Simmonds, 2006; Rasmussen et al., 2008). Figure 6 shows the bioaccessibility of various trace metals in home dust from a temperate coastal city in the United Kingdom and an arid coastal city in Saudi Arabia, with total metal concentrations summarized. Results indicated that trace metals, the amount, order, and phase of bioaccessibility varied dramatically between habitats. In a dry environment, the accessibilities of Ni and Zn were reduced, and U, Cd, and Sn were significantly more complex. Several metals, including lead, have greater convenience in the intestinal tract than in the simulated stomach. Inconsistencies appear to be caused by differences in climate, geology, home architecture and decorating, cooking, heating appliances, and cleaning and living routines. Such explanations make it difficult to draw broad conclusions regarding the mechanisms of metal deployment and subsequent chemical speciation in the digestive environment, and they suggest that standard risk estimates for trace metals in household dust are inadequate (Turner & Simmonds, 2006).

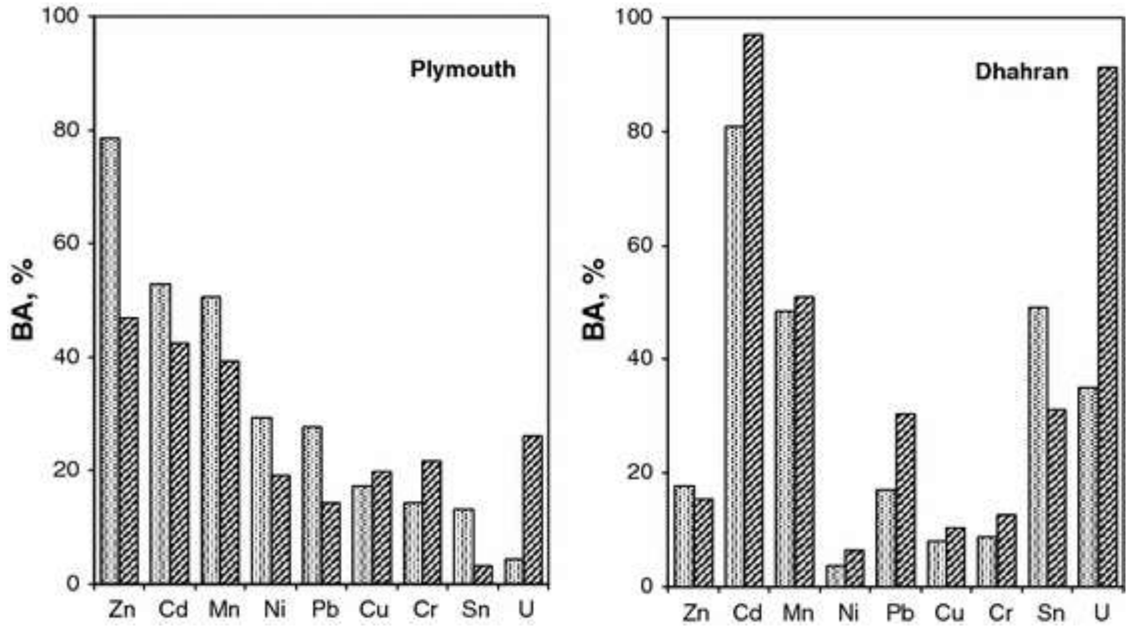

Figure 6: Mean stomach and intestinal bioaccessibilities of numerous trace metals in household dust composed from a temperate, Coastal City in the U.K., and an Arid Coastal City in Saudi Ara (Turner et al., 2006).

Earlier stages of development and child-specific behaviors make younger children more susceptible than adults to heavy metal exposure and toxicity. Childhood is a time of increased gastrointestinal absorption of toxins (about 50% vs. 8% in adults) due to the rapid development and maturation of the brain. Due to their increased breathing rates per unit of body mass and their propensity for frequent hand-to-mouth action (touching and mouthing of various dust-contaminated objects), children may inhale substantial amounts of dust while crawling on the floor. And because kids have a lesser tolerance for pollutants than grownups do, the risks to their health are amplified (Kurt-Karakus, 2012; Zhu et al., 2015).

Children, in particular, are at risk of exposure to trace elements by inhalation of suspended dust particles, skin absorption, and unintentional ingesting of house dust. Many of these trace elements are potentially harmful at high concentrations and function as either initiators or promoters of disease, especially cardiovascular ailments and cancer (Zota et al., 2011).

Inhalation is the primary route of exposure, although ingestion of dust also poses a substantial risk. Children, especially toddlers and infants, intentionally ingest non-food items by placing them in their mouths and chewing on them. This ingestion can occur accidentally through food and drink or mucociliary clearing. As the dust particles make their way through the digestive tract, some of the toxicants they contain are released from the matrix and into the bloodstream (Stapleton et al., 2008).

Human Health Risk Assessment

Given the amount of time that people spend indoors, residential environments are perhaps the most important yet understudied environments with respect to human exposure to contaminants. Globally, people spend up to 90% of their time indoors (Lassen et al., 2005). This increased during COVID-19 lockdowns (Harney et al., 2000). Infants, in particular, spend most of their time at home and indoors (Thatcher & Layton, 1995), moreover, their developing bodies are more sensitive to trace metal exposures. Due to this evolving dependency on the indoors, identifying, characterizing, and mitigating the risk of household contaminants on an international scale is of high importance. The health risks posed to residents from exposure to potentially contaminant-laden dust has been noted. However, the international perspective on the contaminants of common concern to all countries remains relatively unexplored (Thatcher & Layton, 1995; Yakovleva et al., 1999).

Minimizing elevated concentrations of potentially toxic trace metals and metalloids “trace metals" in the home environment remains a persistent issue. It should be targeted as a high priority as exposure can lead to negative lifelong impacts (Weldekidan et al., 2018). Children with higher lead Pb exposures and higher blood Pb concentrations are unlikely to gain the same cognitive abilities in adult life as those less exposed. In addition, Exposure to trace metals is considered an emerging risk factor for neurodegeneration and neurotoxicity (Li et al., 2013). Increased levels of trace metals, including manganese (Mn), Cu, and Zn (have been associated with amyotrophic lateral sclerosis (Weldekidan et al., 2018). Mn levels are associated with Parkinson’s disease, while Pb is associate with adult cognitive decline and Alzheimer’s disease. Thus, the identification of elevated trace metals in the predominant environment of occupation (i.e., homes) is a cause of action to control, reduce and mitigate exposure over a lifetime (Li et al., 2013).

Although this study examines the presence of trace metals in indoor dust and human health risk assessment of trace metals, ICP-Ms was used for the identification of the trace metals present in 71 dust samples collected from the vacuum cleaner. risk assessment of trace metals was conducted using the absorbed daily dosage of trace metals (ADD) and lifetime absorbed daily dosage of trace metals (LADD) that received by a human body through ingestion. In addition, the unidentified gap in this study that other researchers could explore is the detailed health risk assessments of trace metals in the dust and their potential effects by case studies. Here are several ways indoor floor dust enters the body or can come in contact with the body like inhalation, contaminated food, contaminated water, and direct communication via skin.

A number of studies have also revealed that people may be exposed to metals in indoor dust through breathing it in, putting their hands in their mouths, or coming into touch with it on their skin. Because they spend so much time indoors, especially toddlers, and because they frequently put their hands, toys, and other objects in their mouths or eat food that has been contaminated by those same hands, young children can readily swallow soils or indoor dusts unknowingly. Heavy metals emitted from phosphate ore can have detrimental impacts on human health, but little is known about the amounts of these metals in residential buildings near to the P mine. It is therefore important to study the chemical constituents, particularly heavy-metal contamination, in the phosphate rock region and the surrounding areas (Barbieri et al., 2014).

In Hashemi et al. (2020) study collected 42 indoor dust samples and analysed for the presence of zinc, copper, lead, cadmium, nickel, and chromium. These samples were taken from homes (15), offices (10), labs (7), and classrooms (10). A total of 69.12% of zinc, 40% of copper, 43.33% of lead, 798.1% of cadmium, 31.10% of nickel, and 6.31% of chromium were bioavailable in-house dust. Furthermore, risk assessment demonstrated that carcinogenicity and non-carcinogenicity risk values due to heavy metals inside the investigated microenvironments were higher than the EPA's acceptable limit. Heavy metals in these microenvironments were shown to have surpassed the hazardous ecological values reported by several indices, and hence can have significant detrimental ecological effects.

In another study, an important danger to human health is posed by the possibility of exposure to heavy metals through contaminated indoor dust. Indoor dust samples were collected from four universities in Ondo State, Nigeria, for analysis. Dust samples were obtained by wiping down doors, windows, and shelves in classrooms, dormitories, labs, and libraries, then homogenized into a typical composite and tested for Cr, Pb, Cd, Cu, and Zn using a flame atomic absorption spectrophotometer (FAAS). Within the spectrum of this investigation, the mean metal concentration for Cu was highest, whereas the mean metal concentration for Cd was lowest. Non-carcinogenic research found that inhalation was the third most important exposure mechanism after cutaneous contact and ingestion. Despite this, both the hazard quotients and hazard indices were far below than the threshold of one that would be considered unsafe. Exposure to the dust samples analyzed in the study was shown to have no carcinogenic effects (Ajayi et al., 2022).

CHAPTER 3

DESIGN OF THE STUDY

Sampling Procedure

Seventy-one dust samples were obtained from wooden floors using a family vacuum cleaner for this research work. The size of these dust samples was smaller than 125 micrometers. The samples of sieved dust were stored in a freezer at -20° Celsius until they were used for analysis. The analysis included acid digestion, followed by the utilization of an Inductively Coupled Plasma Mass Spectrometry ICP-MS for detecting and analyzing trace metals.

Sample Analysis

Total Trace Element Concentrations

One gram of each dust sample was measured in a Teflon tube and then mixed with 6mL HNO3, 2 ml of hydrochloric acid (HCl), 6mL HNO3, 2mL HCl, and 1mL HF and let to sit at room temperature overnight for acid digestion. The samples were kept at 50^{o}C for two hours or until-they were completely dried and then stored in a desiccator. They were heated for two hours at 105°C. A 0.45 m PTFE syringe filter was used to filter the samples after they were cooled. The filtrate was diluted with ultrapure water to a final volume of 50 mL and stored in plastic tubes in the fridge pending instrumental analysis.

Instrumental analysis

The Inductively Coupled Plasma-Mass Spectrometer model 7700 from Agilent (ICP-MS) was used for the instrumental analysis of Arsenic (As), Cadmium (Cd), Chromium (Cr), Cobalt (Co), Copper (Cu), Iron (Fe), Lead (Pb), Manganese (Mn), Nickel (Ni), Scandium (Sc), Tin (Sn), Titanium (Ti), Vanadium (V), Zinc (Zu). Each targeted trace element underwent an external calibration over 11 concentration levels, from 0.5 to 1000 ppb, before being incorporated into the sample analysis. Integral time was 0.1 seconds, acquisition time was 22.76 seconds, sampling period was 0.31 seconds, RF power was 1550 watts, RF matching was 1.78 volts, carrier gas flow was 0.9 liters per minute, He gas flow was 4.5 milliliters per minute, and nebulizer pump speed was 0.1 revolutions per second. Readings were undertaken as three replicates.

Health Risk Assessment

The health risk assessment was performed by using the (USEPA) modal in this study, I used the absorbed daily dosage and lifetime absorbed daily dosage received by the human body through ingestion.

$$\boldsymbol{ADDing} = \frac{\boldsymbol{Cs \times IgR \times EF \times ED \times CF}}{\boldsymbol{BW \times AT}} \qquad \textbf{(1)}$$

$$\boldsymbol{LADDing} = \left(\frac{\boldsymbol{Cs \times EF \times CF}}{AT}\right) * \left(\left(\frac{\boldsymbol{IgR \times ED}}{\boldsymbol{BW}}\right) Children + \left(\frac{\boldsymbol{IgR \times ED}}{\boldsymbol{BW}}\right) Adult\right) \qquad \textbf{(2)}$$

Where: Cs is a concentration of a constituent in Soil (mg/kg), IgR is the rate of ingestion (Children 200 mg soil/day, Adults 100 mg soil/day), EF is the exposure frequency (350days); ED is the duration of exposure (Children 6 years, Adult 24 years), CF is the conversion factor (0.000001kg/mg), BW is body weight (children 15kg, Adults 70kg) and AT stands for a noncarcinogenic element over a year (356 x ED), and LADD, is calculated for noncarcinogenic elements over a lifetime (356 x 70).

The carcinogenic and noncarcinogenic risk assessment is carried out by calculating various factors.

Non-carcinogenic effect

HQ was calculated through the division of the ADD for exposure routes by a Reference Dose RfD, to estimate noncarcinogenic risks in the dust. The HQ from ingestion exposures is summed to acquire the HQ, with values > 1, indicating potential indicates a likely adverse health effect. In contrast, values < 1 suggest no significant a possible adverse health effect.

$$\boldsymbol{HQ = \frac{ADD(ing\ )}{RfD}} \qquad \textbf{(3)}$$

$$\boldsymbol{HI = \sum HQ} \qquad \textit{\textbf{(4)}}$$

Carcinogenic risk assessment

The carcinogenic risk was also calculated using the calculation below

$$\mathbf{CR = LADD\ (ing\ )\ x\ SF} \qquad \textbf{(5)}$$

Where S.F. = slope factor.

Cancer slope factor (SF), a carcinogen potency factor, and reference dosage (RfD, a non-carcinogenic threshold) are two important toxicity measures. Risk characterization analyses the potential for carcinogenic and non-cancerous risks in adults and children in the study area by combining all collected data to arriving at quantitative estimates of cancer risk and hazard indices. Cr, Cd, As and Ni were treated as potential carcinogenic contaminants, whereas Pb, V and Mn were regarded as non-carcinogenic elements, based on the order of classification group defined by the International Agency for Research on Cancer (IARC, 2011). Carcinogenic and non-carcinogenic risk can be expressed as the Chronic Daily Intake dose obtained from exposure assessment steps multiplied by the

Slope Factor SF. Both non-carcinogenic and carcinogenic risk assessment of trace metals are calculated using RfD and SF values derived largely from USEPA as shown in Table 1.

Table 1: Reference doses (RfD) and Slop factor (SF) of trace metals in ingestion route of exposure.

project	As	Cd	Cr	Co	Cu	Fe	Pb	Mn	Ni	Sc	Sn	Ti	V	Zn
RfD	0.0003	0.0001	0.003	0.0003	0.04	0.7	0.0035	0.14	0.02	ND	0.6	ND	0.005	0.3
SF	1.5	6.3	0.5	ND	ND	ND	0.0085	ND	0.84	ND	ND	ND	ND	ND

Statistical analysis

The Shapiro-Wilk test was used to ensure that all data were normally distributed before analysis. Most of the trace metals studied showed non-normal distributions (p0.001). Thus, it was hypothesized that all trace metals in all sampling environments followed non-normal distributions. trace metal concentrations in house dust were also analyzed using descriptive statistics like mean, standard deviation, median, minimum, and maximum.

CHAPTER 4

RESULTS AND DISCUSSION

RESULTS

Academic and government institutions have taken a keen interest in the topic due to the increasing importance of indoor environments. Multiple studies have shown that indoor dust can absorb many different types of contaminants, including metals (Olujimi et al., 2015). The presentation, analysis, and discussion of field results are the subject of this chapter. The results were presented with the help of relevant tables and charts. To establish the metal absorption in adults and children through ingestion, trace carcinogenic metals were sampled. By reviewing the methodologies provided by the EPA, researchers could determine potential cancer and non-cancer risks of trace metals in indoor floor dust.

Concentration of Trace Metal in Inhabited Dust

A descriptive summary of trace element levels in dust collected by the vacuum cleaner in one household and sieved to separate dust sizes smaller than 125 micrometers, 14 trace metals were observed in inhabited dust where quantities of a variable quantity is presented in Figure 7-9. The concentrations of Pb, Mn, Cr, Cu, and Zn were higher in dust and have increased rates of metal uptake in adults and children through ingestion followed by Ni, Sn, and V have moderately deposited particles in inhabited dust and have moderate metal uptake rates in children and adults through ingestion. The lowest concentrations were measured for As, Cd, Co, Fe, Sc, and Ti.

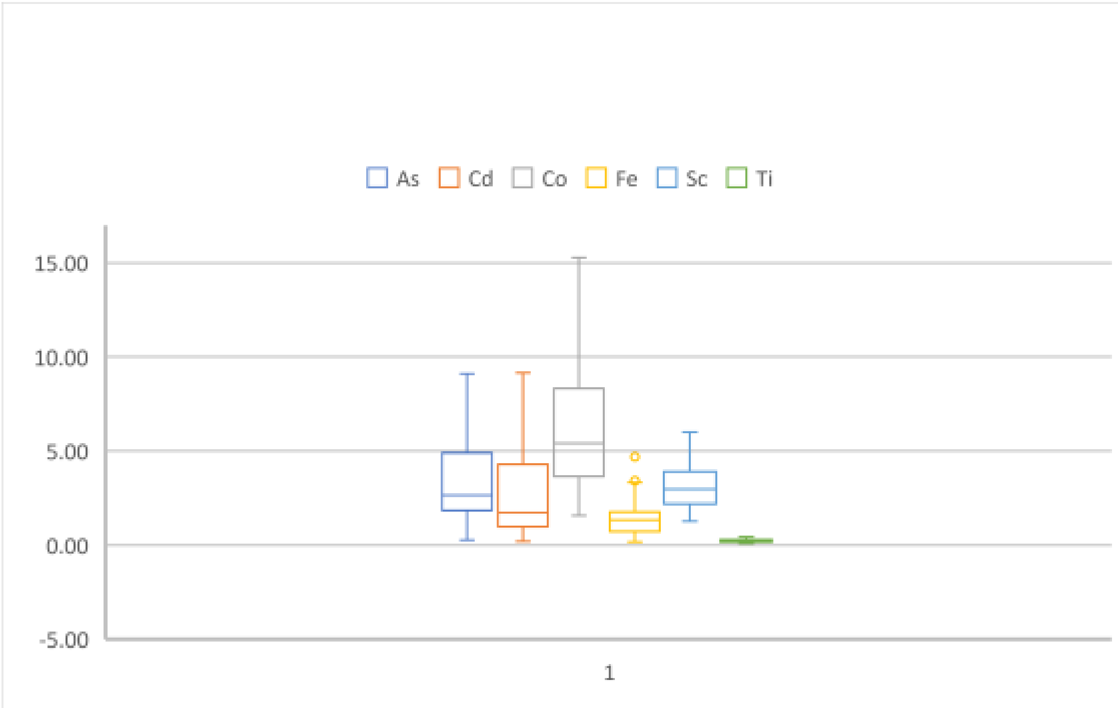

Figure 7:The concentration of different trace metals using the ICP-M.

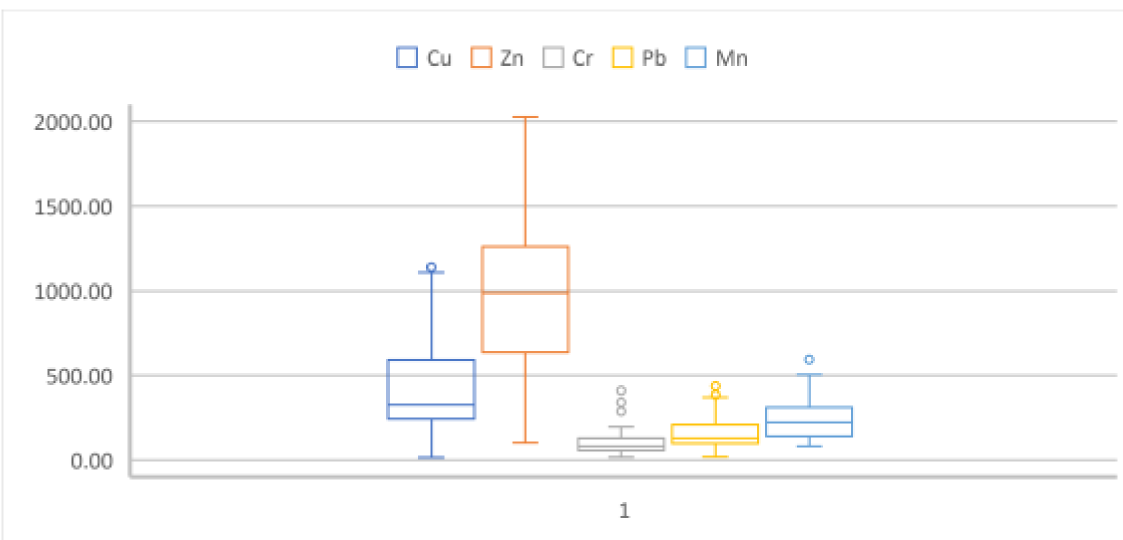

Figure 8: The concentration of different trace metals using the ICP-M.

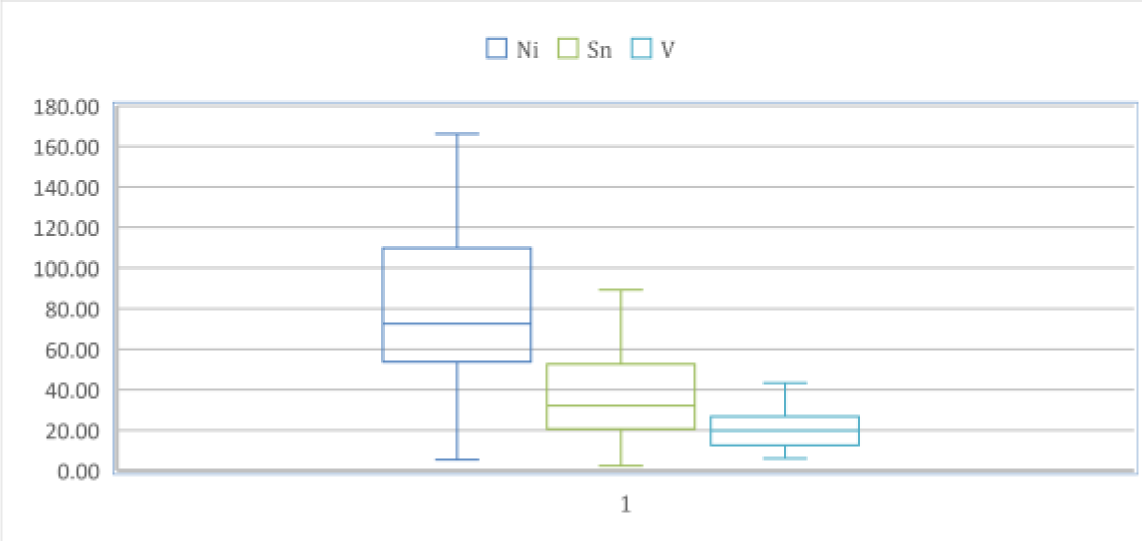

Figure 9:The concentration of different trace metals using the ICP-M.

Health Risk Assessment for Children and Adult.

Human health risk assessment is the process of describing the dangers of pollutants to people (Luo et al., 2015). Group 1 (carcinogenic to humans), Group 2A (probably carcinogenic to humans), Group 2B (possibly carcinogenic to humans), Group 3 (not classifiable as carcinogenic to humans), and Group 4 (not carcinogenic to humans) are the IARC's five categories for carcinogens based on their potential to cause cancer in humans (probably not carcinogenic to humans). According to the International Agency for Research on Cancer's categorization, the heavy metals Al, Co, Cu, Fe, Ni, and Zn are considered to be non-carcinogenic, whereas As, Cd, Cr, and Pb are categorized as possible non-carcinogenic and carcinogenic elements.

Children were shown to be at a greater risk than adults for exposure to indoor dust via ingestion. This finding is a consequence of children's naturally lower body weight and the higher rates at which they ingest dust. The cancer risk for adults in ascending order shows As< Pb < Ni < Cr < Cd had the highest potential cancer risk in adults, while As is the lowest trace metals with potential health risk and low cancer risk through adult ingestion. Co, Cu, Fe, Mn, Sc, Sn, Ti, V, and Zn are trace metals with cancer risk not detected. The cancer risk of children ingestion from trace metals in ascending order shows As<Pb<Ni<Cr<Cd. Thus, Co, Cu, Fe, Mn, Sc, Sn, Ti, V, and Zn are trace metals with cancer risk not detected as shown in figure 10.

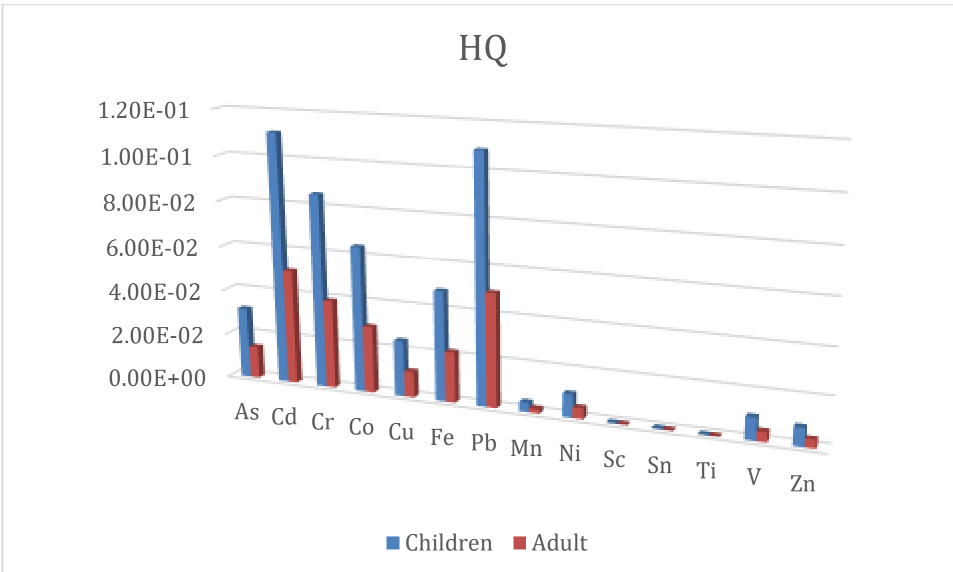

Figure 10: HQ from trace metals in the studied indoor dust.

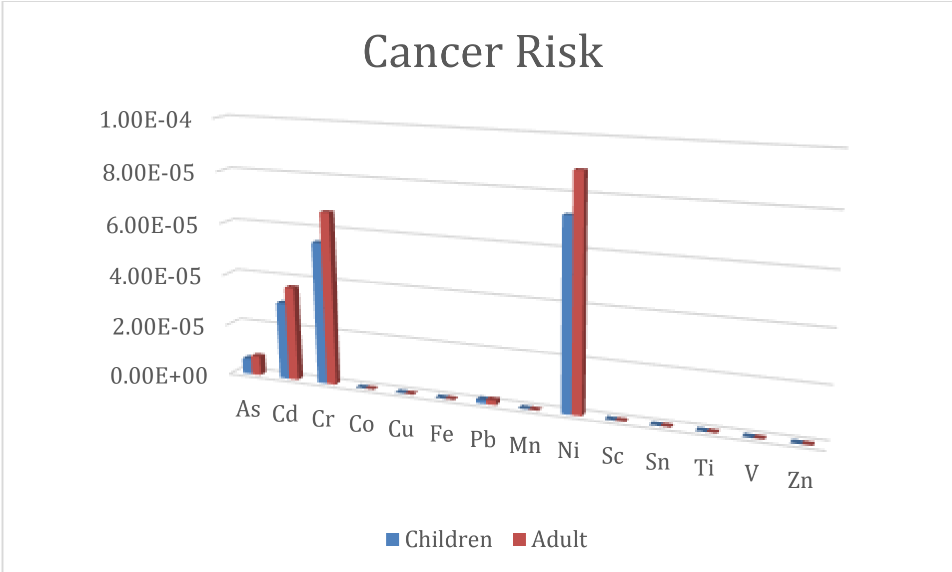

Figure 11: Cancer risk from trace metals in the studied indoor dust.

Non-carcinogenic and Carcinogenic Lifetime Risk Assessment in Children and Adults

The USEPA recommends a threshold of 1.00E−06 which represents a precautionary criterion for carcinogenic risk as mentioned before (Al-Swadi et al., 2022). This means that results were lower than 1.00E−06, thereby indicating a lower risk in both children and adults, while those higher than with 1.00E−06 have higher potential cancer risks. The lifetime cancer and noncancer risks of dust for children and adults via ingestion exposure pathways were calculated and presented in Table 2. Generally, the mean values of CR for Pb were high potential cancer risk. On the contrary, the mean values of CR for the rest elements were a lower risk in both children and adults and have not exceeded the permissible limit set by USEPA, as a result of the non-bioaccumulation nature of trace metals in the body; there may be not a potential non- carcinogenic and carcinogenic risk to humans in the future. From the results, the values recorded for dust samples containing

Fe, As, Cd, Co, Mg, Cr, Cu, Mn, Ni, Sc, Sn, Ti, V, and Zn were lower than the safety limit for adults as prescribed in the precautionary criterion of 1E-06, indicating that the amount of trace metals contained in the dust samples at this stage was not enough to cause carcinogenic and non – carcinogenic risk. The rest metals' cancer risk estimates were significantly lower than the regulatory threshold of acceptability.

Table 2: Lifetime in children and adults due to ingestion of indoor floor dust

Elements	lifetime cancer risk.	Lifetime noncancer risk.	CR_c	CR_{nc}
As	8.95E-06	1.37E-05	1.34E-05	4.57E-02
Cd	1.06E-05	1.62E-05	6.65E-05	1.62E-01
Cr	2.44E-04	3.74E-04	1.22E-04	1.25E-01
Co	1.84E-05	2.82E-05	-	9.39E-02
Cu	9.45E-04	1.45E-03	-	3.62E-02
Fe	3.22E-02	4.94E-02	-	7.06E-02
Pb	3.63E-04	5.56E-04	3.09E-06	1.59E-01
Mn	5.38E-04	8.24E-04	-	5.89E-03
Ni	1.92E-04	2.94E-04	1.61E-04	1.47E-02
Sc	7.27E-06	1.11E-05	-	-
Sn	1.08E-04	1.66E-04	-	2.76E-04
Ti	5.22E-03	8.00E-03	-	-
V	4.74E-05	7.27E-05	-	1.44E-02
Zn	2.34E-03	3.58E-03	-	1.19E-02
Total			*3.66E-04*	*7.39E-01*

Discussion

Trace metals in indoor dust can originate from a wide range of different places, including the state and location of the structure itself, the types of activities taking place within it, and the surrounding environment. Airborne dust containing trace metals can enter a home via a variety of sources, including industry, city traffic, topsoil, building materials, consumer products, and activities carried out inside the home, such as a home renovation or preparing food using a variety of methods (Men et al., 2018).

Our results revealed that the concentrations of Pb, Mn, Cr, Cu, and Zn were higher in dust than Ni, Sn, and V and the lowest concentrations were measured for As, Cd, Co, Fe, Sc, and Ti. Both Rashed (2008) and Zhou et al. (2019) concur with our results. Workshops, laboratories (particularly wet laboratories), and older hostels have the highest metal contents. Dust in the workplace has a disproportionately large amount of metals because of the prevalence of metal cutting, machining, and welding. Metals can seep into historic buildings from rusting metalwork, peeling paint, and other sources.

Zn is one of the highest concentrations found in our study with mean of 1026.06 mg/kg, the zinc in house dust could have come from rubbers and paints. Zn can be released into the indoor environment by mechanical abrasion of home and car components; it is utilized in the fabrication of brass alloy, kitchen dishes, the body of refrigerators, brake pads, oil tanks, gasoline tanks, and cylinder head gaskets (Adamiec et al., 2016). In addition, vulcanised rubber tyre damage, galvanised vehicle parts, lubricating lubricants, and other automotive sources all contribute to Zn in dust (Al-Khashman, 2004). In contract to our study Zn levels were low in another study Zn (Eneji et al., 2015). Again, with the exception of Zn, metal concentrations in the present investigation were higher than those in Jabeen et al. (2001).

Pb concentrations varied from 18.93 to 437.06 mg/kg, with a mean value of 159.24 mg/kg. The use of these metals in construction, decoration, rubber, and braking systems, transportation, lubrication, industrial coloring, product combustion, and even household fuels and cooking all contribute to the accumulation of these toxins in the environment.

Human activities such as building painting, smoking, and penetration into indoor environments in response to emission from automobiles and secondary industrial combustion processes can contribute to the Pb content measured (Luo et al., 2015). Indoor dust in the city of Durgapur, West Bengal, India, has been reported to have an extremely high concentration of Pb (151 mg/kg) by Pal et al. (2018). Poor building maintenance, such as cracked floors and inner walls, can contribute to a high Pb content (Von Lindern et al., 2003). The accumulation of Pb in interior dust is exacerbated by the damage to paintings, carpets, and furniture (Brokbartold et al., 2012). Vehicle and power inverter battery recycling may also produce lead (van der Kuijp et al., 2013). Thus, the elevated Pb concentrations observed in this study are of anthropogenic origin and may be attributable to paint flaking off of older buildings and eventually ending up on the ground as dust (Popoola et al., 2012). In contract to or data Pb levels were low in another study (Darus et al., 2012).

Cu in our study was found in high amount in indoor dust varied from 15.65 to 1138.49 mg/kg, with mean 414.33 mg/kg, Cu is a heavy metal that accumulates in soil and dust as a result of human activities due to its multiple physical features and the vast variety of applications in the production of home appliances such as kitchen equipment, TV antenna, the body of electric equipment, etc (Sulaiman et al., 2017).

Ni in our study was found in moderate amount in indoor dust with mean of 84.22 mg/kg, Ni can be found in a number of automotive byproducts, including brake dust, worn-out tyres, and engine components (Al-Khashman, 2004). Ni is also produced by the exhaust of vehicles (Das et al., 2020). In contrast, studies have documented lower levels for Ni (Zhao et al., 2019; Darus et al., 2012). Compared to previous studies by Lin et al. (2015), Wan et al. (2016b), Doyi et al. (2019), and Neisi et al. (2016), the Ni concentrations in the present study were shown to be moderate.

One of the lowest concentrations were measured was Fe with mean of 1.41 mg/kg. Among the naturally occurring elements found in the planet's crust, Fe ranks high. The frictional production of Fe in soil or roadway dust can cause it to be blown indoors (Darus et al., 2012).

Cd concentration was found 4.63 mg/kg. Yellow paint, used on the majority of the buildings, has been linked to elevated levels of Cd, Pb, Zn, and other heavy metals in interior dust (Chattopadhyay et al., 2003). Stabilizers made from cadmium are used in the production of polyvinyl chloride, an insulating coating used on things like wires and cables (Lau et al., 2014). In parallel with our data, studies have documented lower levels for Cd (Kadili et al., 2017; Popoola et al., 2012; Darus et al., 2012).

The metal concentrations measured in this study were also compared to those measured in other investigations of indoor environments. Metal concentrations were lower than those reported by Yaghi & Abdul-wahab (2004), Rashed (2008), Yadav et al. (2019), Iwegbue et al. (2019), and Li et al. (2020). Adekola and Dosumu (2001) reported lower amounts, with the exception of Zn, in a residential area than either Albar et al. (2020) or Neisi et al. (2016) found. Potential explanations for these discrepancies include distinct geographical study locations and concurrent activity. Results of this study compared with Kurt-Karakus et al. (2012) study suggested that the concentrations of Cd and Cu in indoor dust were high in building painting. Also, Bo˙hlandt et al. (2012) have measured the amounts of cadmium, cerium and lanthanum in indoor air. Households with smokers had a greater concentration of Cd than those without.

Ingestion of polluted dust and dirt is a leading route of exposure for human. Indoor dust is a health risk for children since it can be picked up from the floor, clung to the fibers of furniture, and transferred to other hard surfaces. The term "hand-to-mouth action" refers to the common practice among infants and young children of putting their hands directly into their mouths, which can involve anything from repeatedly mouthing dust-covered toys to putting contaminated fingers into their mouths while eating. Dust levels are increased for children because they are constantly on the floor or carpet. The effects of both short-term and long-term exposure to environmental contaminants are greatest in children (Darus et al., 2012).

Our data showed that the cancer risk for adults in As, Pb, Ni, Cr and Cd had the highest potential cancer risk in adults through adult ingestion. The cancer risk of children ingestion from trace metals in ascending order shows most trace metals with cancer risk not detected. Previous studies have revealed analogous results for house dust. Children's HQs were roughly a factor of ten higher than adults' for all heavy metals. There is a correlation between children's increased susceptibility to harmful chemicals and these results. In addition, kids are especially vulnerable to the effects of heavy metals in household dust because of their habit of putting their hands and mouths directly into their mouths, their penchant for crawling, and their rapid rate of development [24].

In addition, Children may unwittingly eat dust that has clung to their skin. As a result of the dust being suspended in the air, the childrens were at risk of breathing it in (Latif et al., 2014). Our finding agrees with that of previous research (Yeganeh et al., 2013; Chabukdhara and Nema, 2013; Qing et al., 2015; Doabi et al., 2018). As a result, it's important for kids to practise good hygiene by not "hand eating" in public places like playgrounds and schools. consistent with other dust study by Chen et al. (2015); whereas ingestion pathway is one of the main routes of exposure for adults to metals.

Hazard quotient values followed the same sequence; suggesting that humans are more at risk of non-carcinogenic effect when exposed to these heavy metals through the ingestion mode. This is consistent with several reports elsewhere Li et la. (2016) who carried out a study on the Concentrations and Health Risk Assessment of Metal (Loid)s in Indoor Dust from Two Typical Cities of China, whose findings show that The results indicate no distinct pollution of Mn, Ni, As and Ba in the dust, while Cu, Co and Zn are moderate pollution, Pb is significant pollution, and Cr with large pollution range. Most samples presented moderately polluted by metals. The non-cancer risks of the studied metals are within the safe range, and the cancer risks of As, Co, Cr and Ni are also within the currently acceptable range and the work of Olujimi et al. (2015) on Pollution Indexing and Health Risk Assessments of Trace Elements in Indoor Dusts from Classrooms, Living Rooms and Offices in Ogun State, Nigeria, according to their findings Heavy metals are known to have a negative impact on human health especially children through oral ingestion. For human health risk, ingestion was the main route of exposure followed by dermal uptake and inhalation. The carcinogenic risk for As, Cd, Co, Cr, Ni, and Pb were all within the acceptable level (10^{-4}–10^{-6}), but there was potential carcinogenic risk posed by Cr for both adults and children Also the daily intake doses predicted for children are above those for adults irrespective of the pathway.

The CR for Pb was a high potential cancer risk. The university's indoor environment was not found to pose a particularly high risk to human health, according to a preliminary investigation of health risk assessment of trace metals present in the settled dust of diverse typical indoor environments. However, heavy metals may bioaccumulate the human body and cause health issues. The actual duration of exposure, the rate of ingestion, and the quantities of heavy metals in the dust samples are just some of the unknowns that might throw off a health risk assessment (Sulaiman et al., 2017).

In agreement with our study in a Chinese study, Pb contributed the most to the overall value for kid hazards other than cancer. Pb is highly hazardous, therefore it's important to pay close attention to how much of it is building up in the bodies of children in the Xi'an west industrial region. Furthermore, the findings reveal that 94% of Pb is generated from the exposure pathway of dust intake, suggesting that regular hand washing may be a simple but efficient strategy to lower the non-cancer risk of Pb for children in this region. All of the other metals in our study were found at concentrations below the maximum allowed, same as in this Chinese study indicating that residents of Xi'an's western industrial district. These HQs and cancer risks are simply approximations for the general population; actual values may vary by individual because of differences in body weight, exposure frequency, and the bioaccessibility of heavy metals in dust (Wan et al., 2016a).

CHAPTER 5

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The results of this investigation indicated that adults and children are more likely to absorb metals like Pb, Mn, Cr, Cu, and Zn through their diets because of the prevalence of dust with these elements. Particles of Ni, Sn, and V are deposited at moderate rates in populated dust, and children and adults take in these metals at moderate rates through their diets. The remainder of the particle's components has a lower concentration. Ingestion was a more likely route of exposure for both children and adults. Although our study revealed danger levels to be below safe limits, except for Pb levels we did find some evidence that heavy metal levels in indoor dust may be highly variable. One could deduce that increased exposure to heavy metals would lead to an increase in health hazards if the site of the home was chosen without due consideration.

Conclusions

The levels of heavy metals that posed a risk of cancer or other adverse health effects were below the EPA's threshold for tolerance except for Pb levels. One major conclusion can be drawn, however, even though the numerical results of the risk assessment are affected by considerable uncertainty and should be interpreted with caution: children are not expected to develop adverse health effects from exposure to trace elements in household dust alone. Pb, Mn, Cr, Cu, and Zn were trace metals with high absorbed daily dosage and lifetime absorbed daily dosage in both children and adults, as determined by comparing our data to the Environmental Protection Agency's acceptable risk thresholds.

The non-cancer risks to children and adults in all samples were lower than acceptable levels Among both children and adults, Pb was associated with a higher fraction of the minimal risk of non-carcinogenic consequences.

Recommendations

Based on the findings, the following recommendations are made: (a) More attention should be paid to indoor floor dust ingestion in children and adults to reduce the effects it has and to reduce the possibility of causing cancer or posing a health risk to them. (b) More research should be conducted on lowering the concentration of trace metals in indoor floor dust to reduce its effects on children and adults through ingestion. (c) However, more research into metal indicators in bodily fluids including blood and urine is required to establish the negative impacts of metals on human health. (d) Specific measures should be adopted to further reduce environmental exposure risks to soil metals and protect the most vulnerable members of society, including children and adult. Finally, (e) more awareness should be made concerning the effects of trace elements in indoor floor dust. People should be encouraged to go for routine medical checkups, which will help detect if there have been any health risks because of trace elements.

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