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Research Article

Health Risk Assessment of Heavy Metals in the Contaminated Soils of Tehran Province, Iran

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Abstract

Health risk assessment for heavy metals is a suitable technique to environmental planning. Accordingly, soil samples were obtained from three contaminated sites of Tehran Province, Iran. The heavy metals determined by ICP-AES, then health risks calculated for adults and children. The hazard quotient and hazard index values for all heavy metals and pathways were below a safe level in site 1, and all inhabitants were not at non-carcinogenic risk. The HQ of the ingestion pathway in adults and children for site 2 and site 3 were in the following order: Cd>Pb>Cu>Zn. As for adults and children in the three pathways, the HQ values for Pb, Cu and Zn were less than one, meaning that both the adults and children were not at non-carcinogenic risk. The HQ of the ingestion in adults, similarly, HQ of the ingestion and dermal in children for Cd were greater than 1 in 2 and 3 sites, meaning that the Cd was hazard for adults and children. The cancer risk has been calculated based on Pb and Cd. The US Environmental Protection Agency considers acceptable cancer risk within the range of 1×10^{-6} to 1×10^{-4}. Though insignificant in its values, carcinogenic risk for adults in site 1 (2.722×10^{-4}), site 2 (6.67×10^{-4}) and site 3 (9.4444×10^{-4}) and for children on site 1 (5.5×10^{-4}), site 2 (2.203×10^{-2}) and site 3 (1.94×10^{-3}) have been higher than the acceptable values. Hence, the cancer risk for children was more than adults.

Keywords: Heavy metal, Health risk, Carcinogenic risk, Hazard quotient, Hazard index

Introduction

The production and use of chemical materials are increasing worldwide. The potential of public health risks related to exposure to hazardous chemicals is a serious environmental problem (Borhani and Noorpoor, 2017). Development of the urbanization has led to environmental pollutions (Omidvar et al. 2017). Contamination of soil by heavy metal is a main environmental challenge for their toxicity, poor biodegradability and bio-accumulation (Li et al. 2014). There is a growing concern about the heavy metal toxicological effects on the environment, agriculture and human health; this had led to scientific and public awareness of their environmental issues. These heavy metals are released into the environment via anthropogenic activities such as metal plating facilities, mining, and agricultural activities (Karthikal et al. 2016). Their pollution effect and toxicity in soils can be described their solubility and bioavailability. Bio-availability is the major factor considered in assessing the

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potential toxicity of heavy metals (Yang et al. 2012). Human will also be harmed when contact with contaminates soils by heavy metals or breathe them in the dust (Li et al. 2013).

Environmental contamination by heavy metal impacts negatively on human health. Their remediation improves to be problematic due to the persistence and poor degradability of heavy metals (Yuan et al. 2012). The most obvious effect of contamination is to reduce diversity of biological species that are not able to tolerate the toxicants. Heavy metals are hazardous because they tend to associate. Heavy metals can cause serious health effects with varied factors (Adepoju-Bello et al. 2005). The heavy metals like lead (Pb), cadmium (Cd), copper (Cu), and zinc (Zn) are known for their behavior in the environment. The vast increase in environmental contamination by heavy metal puts public health at risk. Various effects of heavy metal contamination in humans are morphological abnormalities, neurophysiological disturbances, mutation, tetratogenesis and carcinogenesis (Idris et al. 2007).

Cadmium derives its toxicological properties from its chemical similarity to zinc an essential element for plants, animals and human. In human, exposure is accumulated with renal dysfunction. High exposure leads to lung cancer. Cadmium could also produce bone defects in human and animals (Adedokun et al. 2016).

Zn and Cu are essential elements of human life, yet excessive intake of these heavy metals can have non-carcinogenic impacts on human health. Higher concentrations of Zn have been accumulated with growth, reproductive impairment, whereas higher amounts of Cu are accumulated with liver disease (Adesuyi et al. 2015; Kamunda et al. 2016). Lead (Pb) is one of the harmful elements that lead to human mutagen and probable carcinogen; it disturbed the normal function of the kidneys, and nervous systems (Kamunda et al. 2016; Aluko et al. 2018). Health risk assessment models were developed. The American model developed by USEPA. The risk assessment is a multi-step procedure that comprises (1) data collection, (2) exposure assessment, (3) toxicity assessment and (4) risk characterization, summarizes and combines the outputs of the calculations of exposure and toxicity assessments (USEPA, 1989). Exposure to pollutants from heavy metals is extremely alarming for child in their first developmental stage and also for the adult population. Chromium, copper, arsenic, cadmium and lead had health effects on humans through food consumption in extra amounts. Incorporation of toxic metals in soils come to the body by food implies a recognized pathway to toxic metal pollutant exposure for children. Chronic toxic metal exposure has a harmful effect on humans and animals (Proshad et al. 2019).

For assessment of potential human health risk, we used the methodology, developed by the Environmental Protection Agency of United States (US EPA) and attempted to estimate non-carcinogenic and carcinogenic risk via four heavy metals (Cu, Cd, Zn, and Pb) concentration for children and adults, separately. In this study, four heavy metals (Cu, Cd, Pb, and Zn) in the contaminated soils in Tehran Province, Iran were determined, and then non-carcinogenic and carcinogenic risk assessment for humans was investigated.

Material and Methods

Soil samples were collected from three contaminated sites by various heavy metals in Tehran Province of Iran: 1Industrial areas which located in Varamin city, 2 and 3 Mallard and Rey cities hazardous waste landfills, respectively.

Sample collection and preparation

Eighteen samples were collected from three sites surface in 2019. Theses soils were selected because of their areal extent (Table1).

Table 1. City, area and number of soil samples

Site	City	Area	Number of samples
1	Varamin	Near Charmshahr industial park	6
2	Malard	Near Mardabad waste landfill	6
3	Rey	Near Ghashie zard waste landfill	6

An auger and spoon were used for sample collection. The moist soil samples were air dried and sieved for removing the particle greater than 2mm. The soil samples kept in plastic bags for analyses. For extraction of heavy metals such as Cd, Cu, Pb and Zn, one gram dried soil was digested in 15 ml mixture of HNO3, H2SO4 and HClO4 (5:1:1) at 80°C, then a transparent solution was obtained. Water samples (50 ml) were digested with 10 ml of concentrated HNO3 at 80°C until the solution became transparent. These transparent solutions were then filtered through Whatman number 42 filter papers and diluted to 50 ml with distilled water. The concentrations of Cd, Cu, Pb and Zn in the filtrate were determined by using Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES), fitted with a specific lamp with particular metal using appropriate drift blanks (Beibei et al. 2017).

Health risk assessment is a process to assess the health effects that might result from exposure to carcinogenic and non-carcinogenic chemicals (USEPA, 2001). The risk assessment has four basic steps: 1) hazard identification, 2) exposure assessment, 3) toxicity (dose-response) assessment, and 4) risk characterization (USEPA, 2001). The purpose of exposure assessment is to survey the intensity, frequency, and duration of human exposure to an environmental pollution. In this study, exposure assessment was conducted by measuring the average daily intake (ADI) of heavy metals, identified earlier through ingestion, inhalation, and skin (dermal) contact with adults and children. Adults and children were divided into separate groups, thanks to their behavioral and physiological differences (Wang et al. 2005). Dose-response assessment estimates the toxicity of exposure levels of the heavy metals. The cancer slope factor (CSF, a carcinogen potency factor) and the reference dose (RfD, a non-carcinogenic threshold) are two important toxicity indexes used (USEPA, 1989; USEPA, 2010).

In this study, the exposure pathways of human exposure to Cu, Cd, Zn, and Pb in soil samples were ingestion, skin (dermal) contact and inhalation. Exposure doses of human exposure to contaminants through these three exposure pathways can be calculated, using the following exposure Equations 1-3 as prescribed by (USEPA, 1989).

(1) Ingestion.

$$ADI_{ing}=\frac{C\times IR\times EF\times ED\times CF}{BW\times AT}$$

Where ADI_{ing} is the average daily intake of heavy metals, ingested from the soil, in mg/kg-day, C indicates the concentration of heavy metal in mg/kg of soil. IR is the ingestion rate in mg/day; EF, the exposure frequency in days/year; ED, the exposure duration in years; BW, the body weight of the exposed individual in kg; and AT, the time period over which the dose is averaged in days. Also CF is the conversion factor in kg/mg.

(2) Skin (dermal) contact C_S

$$ADI_{dermal}=\frac{CS\times SA\times FE\times AF\times ABS\times EF\times ED\times CF}{BW\times AT}$$

Where ADI_{demal} is the exposure dose via skin contact in mg/kg/day. CS shows the concentration of heavy metal in soil in mg/kg, SA stands for the exposed skin area in cm^2. FE is the fraction of the dermal exposure ratio of soil; AF, the soil adherence factor in mg/cm^2; and ABS, the fraction of the applied dose absorbed across the skin. EF, ED, BW, CF, and AT are as defined in Equation 1 before.

(3) Inhalation

$$ADI_{inh} = \frac{CS \times IRair \times EF \times ED}{BW \times AT \times PEF}$$

Where ADI_{inh} stands for the average daily intake of heavy metals, inhaled from the soil in mg/kg-day, CS indicates the concentration of heavy metal in soil in mg/kg, and IR_{air} and PEF are the inhalation rate in m^3/day and the particulate emission factor in m^3/kg, respectively. EF, ED, BW, and AT are as defined earlier in Equation 1. Table 2 presents the exposure factors, used for health risk assessment.

Table 2. Exposure parameters, used for health risk assessment through different exposure pathways for soil (USEPA, 2001)

Parameter	Child	Adult
Body weight (BW) kg	15 kg	70 kg
Exposure frequency (EF) (days/year)	350	350
Exposure duration (ED) (years)	6	30
Ingestion rate (IR) (mg/day)	200	100
Inhalation rate (IRair) (m3/day)	10	20
Skin surface area (SA) (cm2)	2100 cm2	5800 cm2
Soil adherence factor (AF) (mg/cm2)	0.2	0.07
Dermal Absorption factor (ABS)	0.1	0.1
Dermal exposure ratio (FE)	0.61	0.61
Particulate emission factor (PEF) (m3/kg)	1.3×10^9	1.3×10^9
Conversion factor (CF) (kg/mg)	10^{-6}	10^{-6}
Average time (AT) (days) *For carcinogens*	365×70	365×70

Non-carcinogenic risk assessment

$HI = HQ_{ing} + HQ_{dermal} + HQ_{inh} = (ADI_{ing}/RfDing) + (ADI_{dermal}/RfD_{dermal})\ (ADI_{inh}/RfD_{inh})$

Where, HI is a hazard index of non-carcinogens. HQ_{ing}, HQ_{dermal} and HQ_{inh} are hazard quotients of ingestion, skin attaches and inhalation. ADI is average daily dose (mg/kg/day), and RfD is reference dose (mg/kg/day). HQ is the hazard quotient of non-carcinogens, according to the recommended value by USEPA, $HQ \leq 1$ indicates no risk, and $HQ > 1$ indicates that risks do exist (USEPA, 1989).

For carcinogens, the risks are calculated as the incremental probability of an individual developing cancer over a lifetime as a result of exposure to potential carcinogens. The equation to calculate excess lifetime cancer risk is:

$$Risk_{pathway} = \sum_{k=1}^{n} ADI \times CSF$$

Where ADI_k (mg/kg/day) and CSF_k (mg/kg/day) are average daily intake and cancer slope factor, respectively for the k^{th} heavy metal and for n heavy metals. The slope factor converts the calculated daily intake of the heavy metal averaged over a lifetime of exposure directly to the incremental risk of an individual developing cancer (USEPA, 1989).

The total excess lifetime cancer risk for an individual could be calculated from the average portion of the individual heavy metals for all pathways, using the following equation:

$Risk_{total} = Risk_{ing} + Risk_{dermal} + Risk_{inh}$

The non-carcinogenic and carcinogenic risk assessment of heavy metals are calculated using RfD and CSF values, largely derived from the USEPA, as shown in Table 3.

Statistical Analysis

SPSS software was used to perform an analysis of the Duncan multiple range test was used to perform a comparison of means of heavy metals concentration ($P < 0.05$).

Table 3. Reference doses (RfD) (in mg/kg-day) and Cancer Slope Factors (CSF) for different heavy metals (USEPA, 2010; Luo et al. 2012).

Heavy metal	Rfd_{ing}	Rfd_{dermal}	Rfd_{inh}	CSF_{ing}	CSF_{dermal}	CSF_{inh}
Zn	3×10^{-1}	7.5×10^{-2}	-	-	-	-
Pb	3.6×10^{-3}	-	-	1.5	1.5	15
Cu	3.7×10^{-2}	2.4×10^{-2}	-	-	-	-
Cd	5×10^{-4}	5×10^{-4}	5.7×10^{-5}	-	-	6.3

Results and Discussions

Mean concentrations ± standard deviation (mg/kg^{-1}) of heavy metal (Cu, Cd, Pb and Zn) for 18 samples are shown in Table 4. Heavy metal concentrations in this study were in the following order Zn, Cu, Cd and Pb for site 1, Cd, Zn, Cu and Pb for site 2 and Zn, Pb, Cu and Cd for site 3. The significant difference between the Cu, Cd, Pb and Zn levels were in all samples ($p<0.05$).

Table 4. Heavy metal content (Means± SD) for soil samples

Sampling Site	Zn	Pb	Cu	Cd
1	2955±2.2	297.18± 2,2	519.2±2	350.1±1.6
2	1038±2	726.63±2.87	978±2.5	1877.32±3.7
3	1051.5±3.15	1029.5±4.1	952.25±4.3	835.11±3

Cu concentrations are a hazard to plants and some microorganisms. Soluble soil Cu can be harmful to plants since Cu-enriched liquid dairy waste used on agricultural land as irrigation water. Copper in the soil surface, or aerated soil, is usually present as Cu (II). Although most copper salts occur in two valence states, *i.e*., Cu (I) or Cu (II) ions, the biological availability and toxicity of copper is most likely associated with the divalent state (Grzetic and Ghariani, 2008).

In this research, the value of Cu ranged between 519 mg/kg to 978 mg/kg. The maximum amount 978 mg/kg was found at site 2 while minimum 519 mg/kg was found at site 1. Cd concentrations were found between 350.1 mg/kg to 1877.32 mg/kg. The maximum amount (1877.32 mg/kg) was recorded on site 2 and minimum (350.1 mg/kg) was recorded on site 1 (Table 4).

Pb concentration was ranged between 297.18 mg/kg to 1029.5 mg/kg in the study areas. The highest amount of Pb (1029.5 mg/kg) was found at site 3 (Table 4). This excess concentration of Pb found in soil may be due to several anthropogenic factors like metal processing factories (Proshad et al. 2019).

Zinc is an essential element with a recommended daily allowances ranging from 5 mg for infants to 15 mg for adults. Too little zinc can cause health problems, but too much zinc is also harmful. Harmful health effects generally begin at levels in the 100 to 250 mg/day range (Grzetic and Ghariani, 2008). Zn concentrations were found between 1038 mg/kg to 2955 mg/kg. The highest amount (2955 mg/kg) was recorded on site 1 and minimum (1038 mg/kg) was recorded on site 1 (Table 4). Non carcinogenic risk for adults and children were calculated based on ADI values, as shown in Tables 5- 6. The results from ingestion, inhalation, and dermal pathways were all presented in terms of HQs, as shown in Table 7-8 for both adults and children. In risk assessment, when HQ and HI values are below 1, the population was not at risk of any non-carcinogenic effects, but if these values greater than 1, there may be some concern for potential non-carcinogenic effects (USEPA, 2010).

Table5. Average Daily Intake (ADI) values in mg/kg/day for children in the soil samples for non-carcinogenic risk calculations

Site	Pathway	Zn	Pb	Cu	Cd
1	Ingestion	3.24E-03	3.25E-04	5.69E-04	3.84E-04
	Inhalation	1.24E-07	5.2E-08	9.06E-08	6.1E-08
	Dermal	4.15E-04	4.17E-05	7.28E-05	4.9E-05
	Total	3.65E-03	3.66E-04	6.42E-04	4.33E-04
2	Ingestion	1.14E-03	7.96E-04	1.07E-03	2.05E-03
	Inhalation	1.81E-07	1.27E-07	1.7E-07	3.28E-07
	Dermal	1.45E-04	1.02E-04	1.37E-04	2.6E-04
	Total	1.28E-03	8.98E-04	1.2E-03	2.3E-03
3	Ingestion	1.15E-03	1.13E-03	1.04E-03	9.15E-04
	Inhalation	1.83E-07	1.79E-07	1.66E-07	1.46E-07
	Dermal	1.47E-04	1.44E-04	1.33E-04	1.17E-04
	Total	1.29E-03	1.27E-03	1.17E-03	1.03E-03

Table6. Hazard Quotient (HQ) and Hazard Index (HI) values for heavy metals in adults for the soil samples

Site	**Pathway**	**Hazard Quotient (HQ)**			
		Zn	Pb	Cu	Cd
1	Ingestion	5.7E-03	4.8E-02	8.24E-03	4.1E-02
	Inhalation	-	-	1.82E-06	3.93E-05
	Dermal	9.4E-05	-	-	1.67E-03
	Hazard Index (HI)	5.794E-03	4.8E-02	8.242E-03	4.27E-02
2	Ingestion	2.03E-03	1.18E-01	15.5E-03	2.2E+00
	Inhalation	-	-	3.43E-06	2.77E-03
	Dermal	3.3E-05	-	-	8.94E-03
	Hazard Index (HI)	2.063E-03	1.18E-01	15.5E-03	2.71E+00
3	Ingestion	2.05E-03	1.67E-01	15.1E-03	9.8E-02
	Inhalation	-	-	3.43E-06	9.37E-05
	Dermal	3.33E-05	-	-	3.98E-03
	Hazard Index (HI)	2.083E-03	1.67E-01	15.1E-03	1.02E-01

Table 6. Hazard Quotient (HQ) and Hazard Index (HI) values for heavy metals in children for the soil samples

Site	**Pathway**	**Hazard Quotient (HQ)**			
		Zn	Pb	Cu	Cd
1	Ingestion	1.08E-02	9.03E-02	1.54E-02	7.68E-01
	Inhalation	-	-	-	1.07E-03
	Dermal	5.53E-03	-	3.03E-03	9.8E-01
	Hazard Index (HI)	1.633E-02	9.03E-02	1.843E-02	17.49E-01
2	Ingestion	3.66E-03	2.21E-01	2.89E-02	4.1E+00
	Inhalation	-	-	-	5.75E+01
	Dermal	1.93E-03	-	5.7E-03	5.2E-01
	Hazard Index (HI)	5.59E-03	2.21E-01	2.896E-02	6.212E+01
3	Ingestion	3.83E-03	3.14E-02	2.8E-02	1.83E+00
	Inhalation	-	-	-	2.56E-03
	Dermal	1.96E-03	-	5.54E-03	2.34E-01
	Hazard Index (HI)	5.79E-03	3.14E-02	2.805E-02	2.06E+00

Table 7. Cancer risk values of heavy metals for adults in soil samples

Site	Pathway	Cancer risk				
		Zn	Pb	Cu	Cd	Total Risk
1	Ingestion	-	2.61E-04	-	-	-
	Inhalation	-	3.75E-08	-	1.86E-07	-
	Dermal	-	1.062E-05	-	-	-
	Total	-	2.72E-04	-	1.86E-07	2.722E-04
2	Ingestion	-	6.39E-04	-	-	-
	Inhalation	-	9.18E-07	-	9.954E-07	-
	Dermal	-	2.6E-05	-	-	-
	Total	-	6.66E-04	-	9.954E-07	6.67E-04
3	Ingestion	-	9.06E-04	-	-	-
	Inhalation	-	1.3E-06	-	4.43E-07	-
	Dermal	-	3.675E-05	-	-	-
	Total	-	9.44E-04	-	4.43E-07	9.4444E-04

Table 8. Cancer risk values of heavy metals for children in soil samples

Site	Pathway	Cancer risk				
		Zn	Pb	Cu	Cd	Total Risk
1	Ingestion	-	4.875E-04	-	-	-
	Inhalation	-	7.8E-07	-	3.843E-07	-
	Dermal	-	6.255E-05	-	-	-
	Total	-	5.5E-04	-	3.843E-07	5.5E-04
2	Ingestion	-	1.2E-03	-	-	-
	Inhalation	-	1.905E-06	-	2.066E-02	-
	Dermal	-	1.53E-04	-	-	-
	Total	-	1.37E-03	-	2.066E-02	2.203E-02
3	Ingestion	-	1.695E-03	-	-	-
	Inhalation	-	2.685E-06	-	9.2E-07	-
	Dermal	-	2.16E-04	-	-	-
	Total	-	1.94E-03	-	9.2E-07	1.94E-03

For the Adult and child population in site 1, the calculated HQ values for Pb, Cd, Zn, and Cu were less than one in all considered pathways. HI values for all the pathways in adults were also less than one, standing in the following order: Pb>Cd>Cu>Zn and Cd>Pb>Cu>Zn for children. For all the heavy metals considered, the adult and child population in site 1 were not at risk of any non-carcinogenic effects of Pb, Cd, Zn, and Cu.

The HQ and HI values for all the pathways in adult and child population of site 2and site 3 had the same patterns. The HQ of the ingestion in adults and children were in the following order: Cd>Pb>Cu>Zn. As for adults and children, the calculated HQ values for Pb, Cu and Zn were less than one in all pathways, meaning that the adults and children were not at risk of non-carcinogenic effects. The HQ of the ingestion in adults, similarly, HQ of the ingestion and dermal in children for Cd were greater than 1 in 2 and 3 sites, meaning that the Cd was hazard for adults and children. The results indicated that for both child and adult populations of three sites, the inhalation pathway was the least contributor to the risk.

Pb has been presented to affect every organ in the body. Researchers have found that Pb is a toxicant, cardiovascular system, central and peripheral nervous systems, kidneys, immune system, and reproductive system (RAIS, 2008). Irreversible brain damage reported, when the Pb level of blood exceeds 100 μg/dl in adults and 80-100 μg/dl in children (RAIS, 2008). The children and adults in 2 and 3 sites in this study were prone to health risk from Cd toxicity due to their ingestion and dermal pathways. This was translated into cadmium HQ above 1, posing much non-carcinogenic risk.

The HI values reported in the order of Cu (4.63) > Cr (2.64) > Pb (1.11) > Cd (0.57) > Zn (3.82E-03), presented that children were at a higher level of health risk with greater exposure to heavy metals (Aluko et al. 2018). In a study on health risk assessment of heavy metals in soils from the Witwatersrand gold mining basin, South Africa, the HI value for all pathways turned out to be 2.13, making non-carcinogenic effects in adults. For children, the HI value was 43.80, which had serious non-carcinogenic effect on child population (Kamunda et al. 2016). Aluko et al. (2018) observed the HQ values for all heavy metals and all pathways did not exceed 1; similarly, HI values for all pathways were below one, meaning that the adults were not at risk of non-carcinogenic effects. For children, the HQ values for Cd, Zn, and Cu were less than one for all pathways, while Pb and Cr HQ values were greater than one, mainly through the ingestion pathways. The HI values for Pb, Cr, and Cu were above one in the following order: Cr>Pb>Cu. The same results have been reported by Xiao et al. (2017) in soils from partial areas in China; previously, the non-cancer risk of Cu in three pathways is less than Pb. The non-cancer risks, both adults and children are less than 1 and presented a general trend of HQ in ingestion pathway＞HQ in inhalation pathway＞HQ in dermal pathway. The HQ and HI values presented for heavy metals were below a safe level by Chonokhuu et al. (2019). They calculated values of HI for heavy metals in children higher than adults, also they estimated carcinogenic risks through the inhalation exposure, and as a result, there were no significant risks to human health from As, Cr, and Ni heavy metals.

The sum of HI for all heavy metals and all pathways is 10.47×10^{-2}, 2.846×10^{-1} and 2.86×10^{-1}, respectively in adults for three sites, also 1.87×10^{-1}, 6.24 and 2.12 in children. The values adults in three sites and children on site 1 were less than 1, indicated the soils poses no non-carcinogenic risk to adults and children, but the values children in the 2 and 3 sites were greater than 1, showed the soils of these sites had non-carcinogenic risk to children. The non-carcinogenic risk in the previous studies was investigated in China and Nigeria (Olujimi et al. 2015; Li et al. 2013, Hu et al. 2011; Zhang et al. 2012). In this study, Cd contributed 40.77%, 95.27%and 64.36 of non-carcinogenic risk to adults in three sites, respectively. While other contributors are Cu (7.87%, 0.5% and 5.28%), Pb (45.83%, 4.14% and 58.35%) and Zn (5.53%, 0.09 %and 0.73 %) for three sites (Figure 1). Cd contributed 93.33%, 99.59%and 96.94%of non-carcinogenic risk to children in three sites, respectively. While other contributors are Cu (0.98%, 0.05% and 1.32%), Pb (4.82%, 0.35 % and 1.47 %) and Zn (0.87%, 0.009 %and 0.0.27 %,) for three sites (Figure 2).

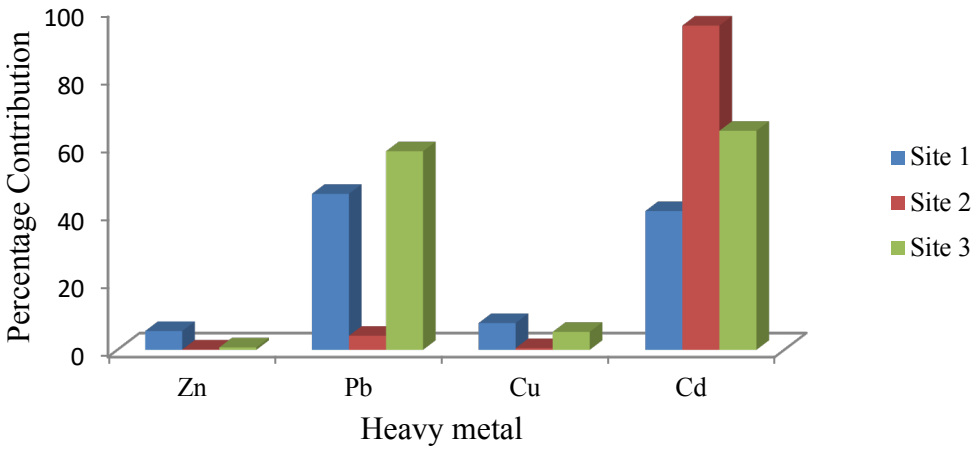

Figure 1. Percentage Contribution of heavy metals to Hazard Index in Adults

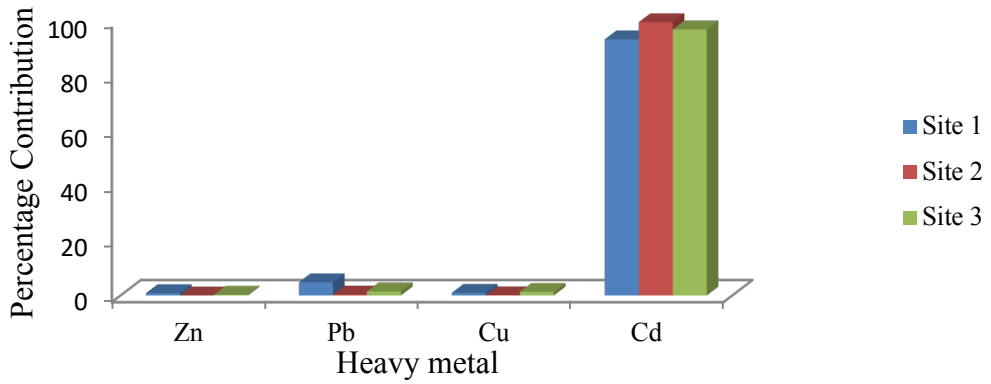

Figure 2. Percentage Contribution of heavy metals to Hazard Index in Children

The heavy metal toxicity depends on their daily intake (FAO/WHO, 2004). The excess lifetime cancer risks for adults and children were calculated, based on carcinogenic risk values of the calculated ADI values, presented in Table 7-8. The carcinogenic risk was calculated based on Pb and Cd. The US Environmental Protection Agency considers cancer risk in the range of 1×10^{-6} to 1×10^{-4} as acceptable (USEPA, 2004). The exposure pathways for all heavy metals being in the following order: Ingestion > dermal > inhalation for both adults and children in three sites in this study. The cancer risk for adults in site 1 (2.722×10^{-4}), site 2 (6.67×10^{-4}) and site 3 (9.4444×10^{-4}) are shown in Table 7, and for children in site 1 (5.5×10^{-4}), site 2 (2.203×10^{-2}) and site 3 (1.94×10^{-3}) were found to be higher than acceptable values.

Therefore, in the current study, for three sites, children were more at risk, and the ingestion pathway to be the main contributor to excess lifetime cancer risk, followed by the dermal pathway. Aluko et al. (2018) reported the cancer risk for adults 2.95×10^{-4} and 4.71×10^{-4}, respectively, for Agbaja and Itakpe. They observed adults were more at risk. In the current study, the cancer risk for Cd and Pb was considered. The percentage contribution for Pb was 100% of adults in three sites (Figure 3). Pb contributed 100% to children on the site 1 and site 3, while Pb and Cd contributed 93.8% and 6.2%, respectively to the site 2 (Figure 4). The heavy metals distribution pattern reported in this study differs from previous studies (Shi et al. 2011; Olujimi et al. 2015).

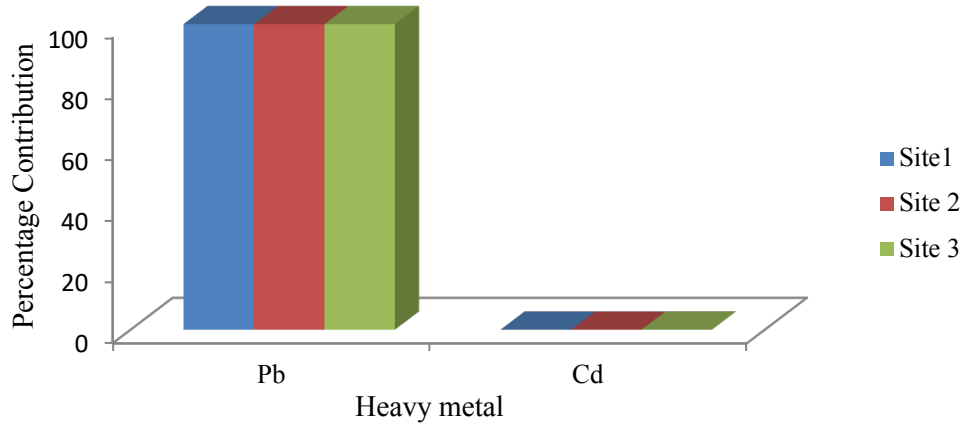

Figure 3. Percentage Contribution of heavy metals to Censer risk in Adults

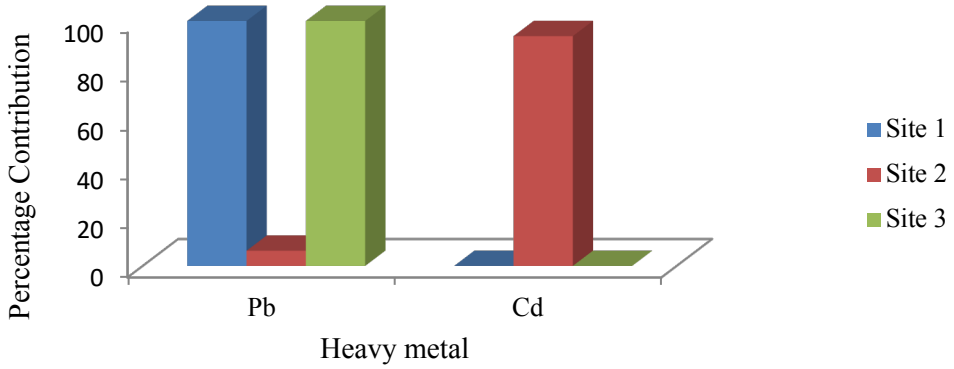

Figure 4. Percentage Contribution of heavy metals to Censer risk in Children

Conclusions

According to this study, for both adults and children, the ingestion pathway is the major contributor to non-carcinogenic and carcinogenic risk, followed by the dermal pathway. The inhalation pathway is the least contributor to non- carcinogenic and carcinogenic risk. The HQ of ingestion of soil samples for all heavy metals was much higher than those of inhalation and dermal absorption. The values of HQ and HI for three pathways of this study decreased in the order of ingestion > dermal contact > inhalation. The finding presented, the soils on site 1 pose no non-carcinogenic risk to adults and children, but the soils of the site 2 and 3, had non-carcinogenic risk to children. For three sites, children were more at cancer risk than adults. Levels of risks regarding cancer were higher than the tolerable range (10^{-6}–10^{-4}) in adults and children, above which the environmental and regulatory agencies perceive the risk to be unacceptable. The ingestion pathway was the major form of exposure for both adults and the children and presented the most probable pathway for risk of cancer development. The results of this study are useful for both residents, in taking protective measures, and government, in alleviating heavy metals contamination, of the environmental planning.

The investigation that remains, which has not yet been done in the scope of this study, is research by biomedical experts which should reveal the exact adverse effects that heavy metal pollution of soil might induce in humans, particularly children.

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