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Cancer and Non-Cancer Risks of Exposure to Some Potentially Toxic Metals (PTMs) In Indoor Settled Dust from Selected Offices

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ABSTRACT

Dust particulate has been reported to harbour a significant level of potentially toxic metals (PTMs), and the risk of human exposure to it has been a major concern. The study aimed to investigate the health risk assessment of exposure to PTMs in indoor dust from selected offices in Abeokuta, Ogun State, Nigeria. Twenty-four (24) composite settled dust samples were strategically collected from offices into a sample bag, and then transported to the laboratory for analysis. A 20 mL *Aqua regia* was used to digest one gram of the prepared sample, then PTM analyzed was done using AOAC Standards. Pollution intensity was evaluated using contamination factors (CF) and enrichment factors (EF). The findings showed that Cu (0.01–5.36 mg/kg), Zn (0.16-48.3 mg/kg), Cd (0.03–0.73 mg/kg), Mn (0.67–50.9 mg/kg), and Pb (3.04–88.3 mg/kg) were present, although within the UK, Canada, and Dutch guidelines. Pollution indexing revealed that the settled dust is severely enriched with Zn (6.58) and Pb (7.79), and

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moderately contaminated with Cd (1.33). Furthermore, the average daily dose (ADD) revealed Zn as the most dosed PTM in the settled dust. Non-cancer and cancer risk assessments showed that the occupants are not at risk of a significant cancer and non-cancer effect. In conclusion, the study showed that the indoor settled dust poses no human health risk during the investigation.

***Keywords*:** Cancer, Non-Cancer, Settled Dust, Offices, Pollution, Toxic Metals

1. INTRODUCTION

Dust consists of particulate or solid matter in the form of fine powder (< 100 μm), lying on the surface of objects and/or on the ground or blown by both mechanical and natural forces (Adekola and Dosumu 2011; Famuyiwa *et al*., 2024). Indoor air pollution with dust and other pollutants such as PTMs may emanate from infiltration of outdoor pollutants and/or vehicle emission or through incense burning, smoking, furniture, and building material or may result from occupants' activities (Rasmussen *et al*., 2014; Famuyiwa *et al*., 2022). Nowadays, the public health is affected by this emission into the air environment (Rashed, 2018). It should be noted that indoor dust is known as one of the important pathways of human exposure to toxic metals.

Therefore, 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 (Chen *et al*., 2014; Chirenje *et al*., 2016), indoor dust monitoring is an important way of determining the origin, distribution, and level of PTMs (Mølhave *et al*., 2010; Kim and Fergusson, 2013). Furthermore, indoor dust contamination is important from the point of view that young children, especially toddlers, spend much of their time in close contact with floors, engaging in mouthing of hands and other objects such as toys, or the consumption of food contaminated by hands (Rashed, 2018; Famuyiwa *et al*., 2022).

PTMS such as As, Cd, Co, Ni, and Pb are the most polluting metals in the urban environment and due to their specific features such as non-biodegradable and persistency, long biological half-life and bioaccumulation potential can pose several adverse effects on human health (Darus *et al*., 2012). PTMs released into the environment may find their way indoors into offices possibly through wind action of dust (Kurt-Karakus, 2012). Trace quantities of some PTMs, such as Cu, are harmless, although, some such as Pb and Cd are neurotoxic for living organisms including humans. Manganese, Cd, Cu, Pb and Zn are reported to be initiators or promoters of carcinogenic activities **(**Famuyiwa *et al*., 2022**)**.

Studies on PTMs in indoor dust in sensitive environments such as schools, home and offices have been conducted by Darus *et al*. (2012), Chen *et al*. (2014) and Famuyiwa *et al.*, 2024). All of these studies were more focused on PTMs composition and source identification of indoor dust (Shi *et al*., 2011). However, few of these studies assessed the health risks of the PTMs on exposure. Information on multiple exposure pathways (ingestion, inhalation, and dermal) of indoor dust is crucial to update the limited information available concerning the likelihood of health risks attributed to PTMs indoor dust in environments, such as offices in Abeokuta. Therefore, the study was conducted to assess the pollution and health risks of PTMs in indoor settled dust sampled from selected offices in Abeokuta. The finding of this study is crucial as evidence of environmental processes, and the impacts surrounding the office area will demonstrate the health risk implications of its occupants.

2. MATERIALS AND METHODS

2. 1. Study area

Abeokuta is located on a crystalline pre-Cambrian basement complex of igneous and metamorphic origin in Ogun State, Nigeria. Its latitude is 7°9'39"N and its longitude is 3°20'54"E. The National Population Commission (2006) estimates that there are 593,140 people residing in and around Abeokuta. Abeokuta is home to many traditional quarry processors, and the region's chief products include industrial and mechanical wastes, electronics casings, and series metalloid materials. In addition to being a great location for local industries including canning plants, plastics, breweries, sawmills, and aluminium product factories, the southern half of the area is home to granite mining and quarries. Figure 1 depicts the map of Abeokuta from Ogun state according to Umoren *et al*. (2024a).

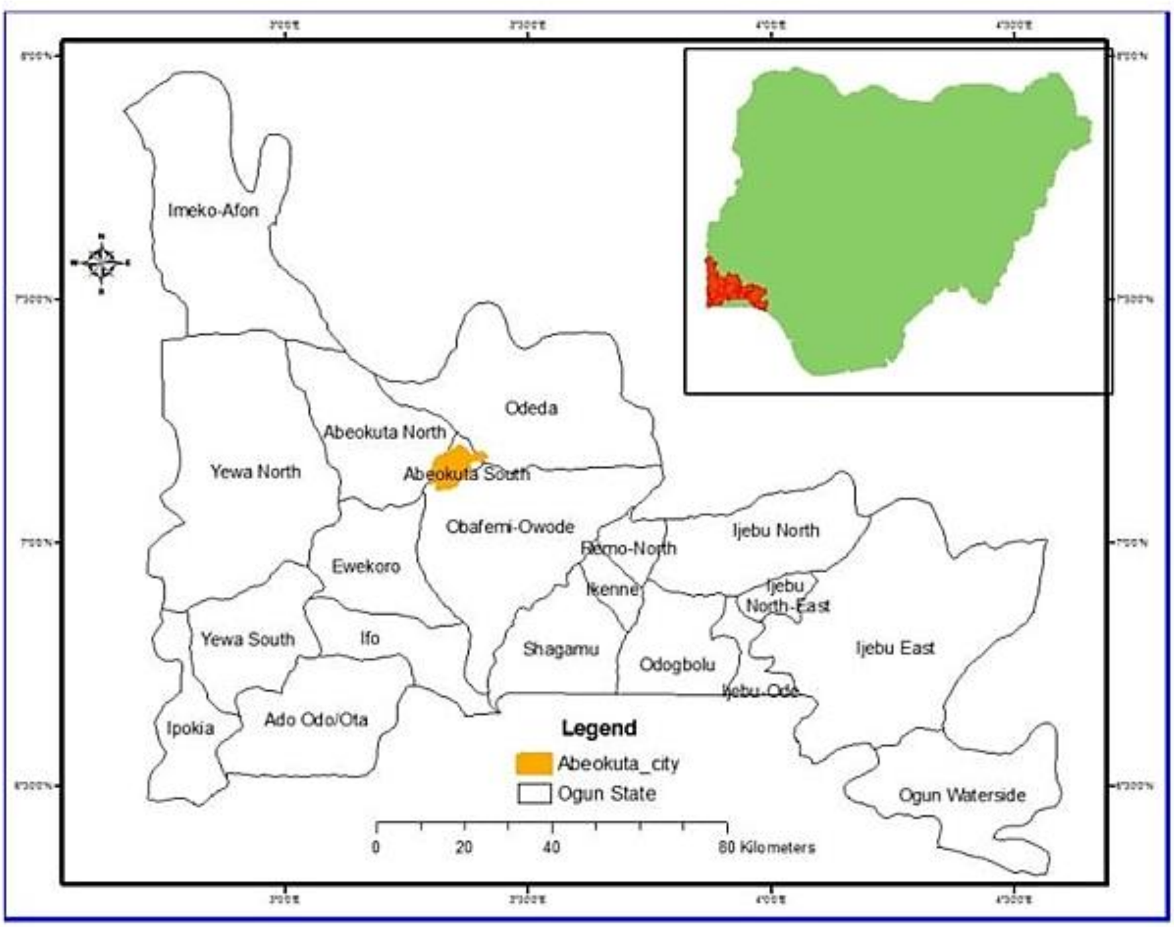

Figure 1. Map of Abeokuta City from Ogun State, Nigeria.

2. 2. Samples Collection and Preparation

A total of twenty-four composite samples from 7-8 sub-samples were collected in January 2024 from strategically selected offices in Abeokuta, Ogun state, Nigeria. Samplings were done by gently sweeping the floors, corners of landscape buildings, window sills, steps and pavements with a sterile brush. At least 5 g of indoor dust was collected and transferred into re-sealable sample bags and clearly labelled. The sample bags were moved to the laboratory and sieved (1 mm size mesh) to eliminate any debris such as visible hair, soil, and grit. The dust samples were oven-dried at 45 °C for 48 hours and homogenized completely.

2. 3. Samples Digestion

One gram of the dust sample was weighed into the digestion flask; 20 mL of mixture of HNO_3 and HCl in a ratio 1:3, was added into the flask. This was heated in a fume cupboard without time reference until the solution turned colourless indicating full digestion. Finally, the digest was allowed to cool and then transferred into a volumetric flask (50 mL), then deionized water was added to dilute to mark and then filtered with Whatman (no 42) filter paper into a sample bottle for further analysis using Atomic Absorption Spectrophotometer (AAS).

2. 4. Contamination Factor (CF)

The level of contamination of the dust samples by metals was assessed with CF as proposed by CF and was calculated using Equation 1.

$$Contamination\ factor\ (CF) = \frac{C_m sample}{C_{ref}} \qquad \text{Equation 1}$$

where: *the* C_m sample is the concentration of the metal in the dust and C_{ref} is the concentration of the metal in the reference or background sample.

2. 5. Enrichment Factor (EF)

Enrichment factors (EF) of PTMs can provide useful information about the degree of enrichment of the metals in dust samples compared to their abundance in the earth's crust (REF). Moreover, the EF can be used to distinguish between the metals originating from human activities (anthropogenic sources) and those from natural origin. The EF can be calculated from the following equation 2 (Lu *et al*. 2014):

$$\text{Enrichment Factor (EF)} = {}^{Cx}/_{Cref_{Sample}} \times {}^{Cx}/_{Cref_{Crust}} \qquad \text{Equation 2}$$

where: Cx is the concentration of the metal of interest and Cref is the concentration of the reference metal for normalization.

2. 6. Health Risk Assessment (HRA)

Health risk assessment (HRA) is the United States Environmental Protection Agency (US EPA) health risk model developed to estimate the potential health risk of contaminants posed to humans. HRA consists of four main components, namely, hazard identification, exposure assessment, dose-response assessment, and risk characterization (Luo *et al*., 2012). Indoor dust has three major pathways, namely, intake by direct ingestion of dust, skin absorption of heavy metals adhered to dust particles, and through mouth and nose inhalations of re-suspended particles (Umoren *et al*., 2024b). The parameters utilized in the evaluation of health risk resulting from various exposure paths is presented Table 1.

Table 1. Exposure parameters used for the health risk assessment through different exposure pathways.

Parameter	Unit	Child	Adult
Body weight (*BW*)	Kg	15	70
Exposure frequency (*EF*)	days/year	180	365
Exposure duration (*ED*)	Years	6	24
Ingestion rate (*IngR*)	mg/day	200	100
Inhalation rate (*InhR*)	m^3/day	7.63	20
Skin surface area (*SA*)	cm^2	2800	3300
Soil adherence factor (*AF*)	mg/cm^2	0.2	0.7
Dermal Absorption factor (*ABS*)	None	0.1	0.1
Particulate emission factor (*PEF*)	m^3/kg	1.36×10^9	1.36×10^9
Conversion factor (*CF*)	kg/mg	$10\times^6$	$10\times^6$
AAverage time (*AT*)	Days	25550	25550

To evaluate HRA via major three pathways, the average daily dose value (ADD) (mg/kg/day) of a contaminant was applied via ingestion (ingest), dermal contact (dermal), and inhalation (inhale) exposure pathways. Equations 3 -5 were used to estimate ADD via ingestion, dermal contact, and inhalation exposure pathways.

$$ADD_{ingestion} = \frac{C_{dust} \text{ x IngR x EF x ED}}{\text{BW x AT}} \text{ x CF} \qquad Equation\ 3$$

$$ADD_{dermal} = \frac{C_{dust} \text{ x SA x AF} \times \text{ABS x EF x ED}}{\text{BW x AT}} \text{ x CF} \qquad Equation\ 4$$

$$ADD_{Inhalation} = \frac{C_{dust} \text{ x InhR x EF x ED}}{\text{PEF x BW x AT}} \qquad Equation\ 5$$

2. 7. Cancer and Non-Cancer Risk Assessment

HRA (non-carcinogenic risk) was determined by using ingestion (ing), inhalation (inh), and dermal (derm) pathways. For non-carcinogenic risk, each element and exposure pathway is subsequently divided by the corresponding reference dose (RfD) to yield a hazard quotient (HQ) as shown in Equation 6. HQ calculated for each element was summed and expressed as a hazard index (HI) (Famuyiwa *et al.,* 2024; Umoren *et al*., 2024c), as shown in Equation 7, to assess the overall potential risks posed by more than one heavy metal. HI value of less than 1 indicates no significant risk of non-carcinogenic effects. HI value exceeding 1 indicates that non-carcinogenic risk effects may occur, with a probability which tends to increase as the value of HI increases.

$$Hazard\ Quotient\ (HQ) = {}^{ADD}/_{RfD} \qquad \text{Equation 6}$$

$$Hazard\ Index\ (HI) = \Sigma HQ_i \qquad \text{Equation 7}$$

The reference dose (RfD) multiplied by the corresponding cancer slope factor (CSF) in mg/kg is used to determine the cancer risks to occupants. A cancer slope factor, calculated using Equation 8, is the upper bound likelihood that the occupants would get cancer as a result of exposure to the polluted settled dust during their lifetime.

$$TCR = ADD\ \times CSF \qquad \text{Equation 8}$$

where: TCR is total cancer risk, that is the likelihood that a person will get any kind of cancer from lifetime exposure to cancer-causing factors. If TCR is less than 1×10^{-6} it specifies negligible cancer risk, while above 1×10^{-4} recommends high cancer risk to humans on exposure (Umoren *et al.,* 2024b; 2024c).

2. 8. Statistical analysis

Data were analyzed using SPSS (version 21) for descriptive statistics while Microsoft Excel (version 2016) was used for computing the pollution index, health risk assessment and data visualizations.

3. RESULTS AND DISCUSSION

3. 1. Concentration of PTMs in Settled Dust

The primary source of cadmium (Cd) in the settled dust is the infiltration of automobile exhaust and contaminated particles. The mean concentration of Cd in the present study ranges from 0.03 to 0.73 mg/kg with a mean value of 0.40±0.21 mg/kg. The Mean Cd concentration from the study was similar to the studies from dust (0.84 mg/kg) in Istanbul, Turkey by Kurt-Karakus (2012) but lower than dust (3.1 mg/kg) from Bushehr, Iran by Ardashiri and Hashem (2017).

Copper (Cu) is an essential trace element required for proper health at an appropriate limit (Nair *et al*., 2014). The concentration of Cu ranges from 0.01 to 5.36 mg/kg with a mean value of 0.69±1.18 mg/kg. The result reported in this study is lower than the report from indoor dust (12.21 mg/kg) from Sri Serdang, Malaysia by Sarva *et al*. (2015) and dust (100 mg/kg) in Xi'an, China by Lu *et al*. (2014bb).

Manganese (Mn) is among the more abundant elements in the earth's crusts and is widely distributed in the environment (Shrivastava and Mishra, 2011). The concentration of Mn ranges from 0.67 to 50.9 mg/kg with a mean value of 8.64±14.5 mg/kg. The mean concentration of

Mn in the study is lower than the report from settled dust in Toronto, Canada (22.5 mg/kg) by Ahmed, (2015) and extremely lower in dust (100 mg/kg) from Xi'an, China by Lu *et al*. (2014b).

Lead (Pb) contamination of the environment is primarily due to anthropogenic activities, making it the most ubiquitous toxic metal in the environment. Lead toxicity can result in brain, and digestive system damage most especially in children (Wani *et al.*, 2015; Sobhanardakani *et al.*, 2018). The concentration of Pb from the study ranges from 3.04 to 88.3 mg/kg with a mean value of 10.9±16.7 mg/kg. The mean Pb concentration reported in this study is lower than the reported in indoor settled dust (16.9 mg/kg) in Toronto, Canada by Ahmed (2015) and indoor dust (171.3 mg/kg) from Khorramabad City, Iran by Ehsan and Soheil (2018).

Zinc is an essential trace element because very small amounts are necessary for human health. Zn toxicity causes headaches, nausea, vomiting and diarrhoea (Willoughby and Bowen, 2014). Zinc products in the office include paint pigments, batteries, roofing materials, and electrical gadgets (Famuyiwa *et al*., 2022). The concentration of Zinc in the study ranges from 0.16 to 48.3 mg/kg with a mean value of 29.4±14.3 mg/kg. The concentration recorded in this study is lower than the report from settled dust (1000 mg/kg) in Toronto, Canada by Ahmed (2014) and in indoor dust (> 1000) in Bushehr, Iran by Saeed and Seyed (2017).

3. 2. Pollution indexing

3. 2. 1. Contamination factor (CF) and Enrichment Factor (EF)

The CF and EF for the PTMs can provide useful information about the degree of pollution in dust samples compared to their abundance in the earth's crust (Lu *et al*. 2014). The CF and EF values of PTMs in settled dust are presented in Table 2.

The CF revealed that the settled dust has moderate contamination with Cd and low contamination with Cu, Mn, Pb and Zn. The CF value follows the trend: Cd > Pb > Zn > Mn > Cu. The EF revealed that the settled dust has an average enrichment with Zn, moderate enrichment with Pb and minimal enrichment with Cd, Cu and Mn. The EF value follows the trend: Pb > Zn > Cd > Mn > Cu.

The EF value for all the PTMs was less than 10 but higher than 1, suggesting a partial emergence from anthropogenic and natural sources.

Table 2. Descriptive statistic, contamination factor (CF) and enrichment factor (EF) for PTMs in dust (N=24).

PTMs (mg kg^{-1})	Mean± Std. Dev.	Range (Min-Max)	Soil Guideline Values (SGV)			CF	EF	Degree of Pollution
			[a]UK	[b]CSGV	[c]DIV			
Cd	0.40±0.21	0.03-0.73	150	22	12	1.33	2.84	Moderately contamination/ Minimal enrichment
Cu	0.69±1.18	0.01-5.36	-	140	190	0.02	0.33	Low Contamination / Minimal enrichment
Mn	8.64±14.5	0.67-50.9	-	-	-	0.05	1.00	Low Contamination / Minimal enrichment

Pb	10.9±16.7	3.04-88.3	450	140	530	0.37	7.79	Low Contamination / Moderate enrichment
Zn	29.4±14.3	0.16-48.3	-	360	750	0.31	6.58	Low Contamination / Average enrichment

[a.] Environment Agency, UK. (2013): Soil guideline values. Accessed July 2023. Available at https://www. gov. uk/government/organizations/environment-agency

[b.] Canada Soil Guideline value (CSGV), (2009): Accessed July 2023. Available at https://ccme.ca/en/current-activities/canadian-environmental-quality-guidelines

[c.] Dutch Target and Intervention Values (DIV). (2000). (The New Dutch List). Hague, Netherlands: The Ministry of Housing, Directorate-General for Environmental Protection; 2000. Accessed July. 2024.

3. 3. Health Risk Assessment

3. 3. 1. Average Daily Dose

The average daily dose (ADD) of PTMs is represented in Table 3, the ADD of PTMs in the settled dust reveals that Zn is the most dosed PTM and the dosage appears in the order of ingestion>dermal>inhalation in children and adults, pointing ingestion has the major pathway of exposure. More so, it also indicated that the adults are more vulnerable to exposure than the children. The exposure to individual PTM in the settled dust is in the order of Zn>Mn>Pb>Cd>Cu for humans in the environment.

Table 3. Average Daily Dose of PTMs in dust.

Human	Pathways	Cu	Zn	Cd	Mn	Pb
Adult	ADD_{ing}	6.76E-07	2.88E-05	3.92E-07	3.91E-06	7.17E-06
	ADD_{inh}	4.97E-11	2.11E-09	2.88E-11	2.87E-11	5.27E-10
	ADD_{dermal}	7.80E-07	3.32E-05	4.52E-07	4.51E-06	8.27E-06
Children	ADD_{ing}	5.14E-08	2.19E-06	2.98E-08	2.97E-07	5.45E-07
	ADD_{inh}	1.09E-11	4.64E-10	6.32E-12	6.31E-11	1.16E-10
	ADD_{dermal}	3.89E-07	3.89E-07	3.89E-07	3.89E-07	3.89E-07

3. 3. 2. Non-cancer and Cancer Risk

Cancer and non-cancer risk associated with PTMs in the settled dust presented in Tables 4 and 5, revealed that the HI value for PTMs was less than 1, suggesting a non-adverse non-cancer risk for the occupants. Furthermore, the total cancer risk (TCR) value for PTMs of exposure is also within the threshold limit (1×10^{-6} - 1×10^{-4}) indicating a negligible cancer risk to the human.

Table 4. Non-Cancer Risk of Exposure.

Category	**Parameters**	**Cu**	**Zn**	**Cd**	**Mn**	**Pb**
Adult	HQ_{ing}	1.69E-05	9.58E-05	3.92E-04	8.50E-05	2.05E-03
	HQ_{inh}	1.24E-09	7.05E-09	2.88E-08	2.01E-05	1.57E-07
	HQ_{dermal}	6.50E-05	5.53E-04	4.52E-02	2.45E-03	1.58E-02
	HI	8.19E-05	6.49E-04	4.56E-02	2.56E-03	1.78E-02
Children	HQ_{ing} HQ_{inh} HQ_{dermal}	1.29E-06 2.71E-10 3.24E-05	7.29E-06 1.55E-09 6.48E-06	2.98E-05 6.32E-09 3.89E-02	6.46E-06 4.41E-06 2.11E-04	1.56E-04 3.29E-08 7.41E-04
	HI	3.37E-05	1.38E-05	3.89E-02	2.22E-04	8.97E-04

Table 5. Cancer Risk of Exposure.

Category	**Parameters**	**Cd**	**Mn**	**Pb**
Adult	CR_{ing}	-	5.86E-06	6.10E-08
	CR_{inh}	1.33E-08	4.31E-09	2.21E-11
	CR_{dermal}	-	6.76E-06	-
	TCR	1.33E-08	1.26E-05	6.09E-08
Children	CR_{ing}	-	4.46E-07	4.64E-09
	CR_{inh}	3.98E-11	9.46E-10	4.86E-12
	CR_{dermal}	-	5.83E-07	-
	TCR	3.98E-11	1.03E-06	4.64E-09

4. CONCLUSION

The study investigates the cancer and non-cancer risks of exposure to PTMs in indoor settled dust in some offices in Abeokuta, Ogun state Nigeria. The findings study showed the presence of Cu, Zn, Cd, Mn and Pb at a concentration of the guidelines values. The settled dust was observed to be severely enriched with Zn and Pb and moderately contaminated with Cd). Non-cancer and cancer risk assessments showed that the occupants are not at risk of a significant non-cancer or cancer effect. Therefore, the indoor settled dust poses no human health risk at the time of the investigation.

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