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Pollution and Health Risk Assessment of Potentially Toxic Elements in Indoor Dusts from Selected Offices in Adodo-Ota Local Government Area, Ogun State Nigeria

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ABSTRACT

Environmental contamination appears to be a significant concern with various possible disastrous aftermaths. The study aimed to investigate the pollution and health risk assessment of potentially toxic elements (PTEs) in indoor dusts from selected offices in Adodo-Ota local government area (LGA), Ogun State Nigeria. Ten (10) composite dust samples were strategically collected from various offices into a sample bag, then transported to the laboratory for analysis. *Aqua regia* acid digestion was used to digest 1g of the dust sample while Atomic Absorption Spectrometer was used for PTE estimation. Degree of pollution was determined using geo-accumulation index and enrichment factor. Results from the study showed that the level of Pb and Zn in 40% and 20% of the samples respectively were higher than the Canada soil/dust guidelines value (CSGV) while Cd, Pb and Zn were the major pollutants in the indoor dust based on I-geo and EF estimation. This could be linked to wall paints, Zn-coated equipment, roofing sheet from ancient buildings and dust infiltration from an outdoor environment. Health risk assessment showed that the occupants were free from a significant non-carcinogenic risk but there is a concern for the value of Pb and Co on children; due to their closeness to the threshold limit. Furthermore, the occupants have a one in hundred thousand chance of developing cancer on equally prolonged exposure to the dust excluding Pb in children. Therefore, our study showed that the examined indoor dusts are polluted with some PTEs.

Keywords: Health Risk Assessment, Indoor Dust, Offices, Pollution, Toxic Elements

INTRODUCTION

Environmental pollution is a major global health issue that has sparked a slew of scientific studies around the world. One of the most serious issues for human health, according to researches is the condition of indoor air (Massey *et al.*, 2013). Dusts are solid particles ranging in size from 1 to 100 microns in diameter that can become airborne depending on their physico-chemical properties (Mohammed and Crump, 2013).

Interior particulates can be observed on floors in a settled state or exposed to the air. Particulates come from a variety of places, including asbestos, soil, pesticides, shed skin, moving in and out, incense burning, transportation or generator emissions, and colorants in paints from walls etc. (Olujimi *et al.*, 2015). Indoor air quality with dust and other pollutants, especially potentially toxic elements (PTEs) can result from infiltration of outdoor pollutants and/or vehicular emissions, as well as incense burning, smoking, furniture and building materials (Rasmussen *et al.*, 2001).

Atmospheric pollution PTEs has a negative impact on public health nowadays (Rashed, 2018). Surprisingly, indoor dust is one of the most common routes of human exposure to PTEs, since humans spend so much of their time indoors and the elements in dust may enter the body via inhalation, Ingestion, absorption or skin contact, studying indoor dust is an interesting way to figure out where PTEs come from, where they go, and how much of them are in the dust (Mølhave *et al.*, 2010). Estimating PTE concentration in interior dust is crucial since young children, especially infants, have so much of the time in connection with floors, mouthing hands and other items such as dolls, or eating food contaminated with dust which can lead to accidental ingestion of PTE (Rashed, 2018).

PTE studies in indoor dust have been widely published in countries such as Australia, Nepal, China, Saudi Arabia, Canada, and others, although few have also been published in Nigeria for example in homes, schools, classrooms, cyber cafés, and other places but there are scanty literatures on indoor dust from Offices. The study

therefore, aimed at evaluating the pollution and health risk assessment of PTEs in indoor dusts from selected offices in Adodo-Ota LGA Ogun State, Nigeria.

MATERIALS AND METHODS

Description of the Study Area

The study was carried out in some offices from Adodo-Ota local government area (LGA) of Ogun state, one of nineteen local government areas, estimated to be the second largest in Ogun State, South-West Nigeria. Coordination 6^o 38'N and 3^o 06'E. It is an industrial local government area with the largest number of industries in the state, it has an area of 878 km^2 and an estimated population of 526,565 as at the last census in 2006. It is primarily agricultural, producing cassava, cocoa, kola nut, maize and minerals such as glass and silica sand; and gypsum. It is indigenous to the Awori people a subset of the Yoruba tribe.

Collection of Samples, Digestion and PTE Estimation

Ten (10) composite dust samples were collected from selected offices using plastic brush to remove dusts from window slit, fan and corner of rooms into a clean polythene sample bag, then transported to the laboratory for analysis.1g of the sample was digested using 20cm^3 of mixed concentrated nitric acid (HNO_3) and hydrochloric acid (HCl) in ratio 1:3. The digest were cooled off, filtered and diluted with deionized water up to 50cm^3, diluent was subjected to Atomic Absorption Spectrophotometry (Model: ICE3000AA01143203VI:30) for PTE estimation.

Degree of Pollution in Dust

Geo-Accumulation Index (I-geo)

The method for calculating the I-geo was according to Lu *et al.* (2014) and Famuyiwa *et al.* (2018) as stated in equation 1

$$\text{I-geo} = \text{Log}\,2\left(\text{Conc. of PTE} / 1.5 \text{ x Background Conc.}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where, Conc. of PTE is the concentration of PTE in the dust, Background Conc. is concentration of PTE in shale and 1.5 is the factor compensating the background data (correction factor) due to geogenic effects.

Enrichment Factor (EF)

The method for estimating the EF was according to Famuyiwa *et al.* (2018) and Carleton *et al.* (2019) as stated in equation 2.

$$EF = \frac{\text{Conc. of PTE in dust}}{\text{Conc. of ref. PTE in dust}} \Big/ \frac{\text{Conc. of PTE in Earth Crust}}{\text{Conc. of ref. PTE in Earth Crust}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where, Conc. of PTE in dust is the concentration PTE in the indoor dust, Conc. of ref. PTE in dust is the concentration of reference PTE in the indoor dust, Conc. of PTE in earth crust is the concentration of PTE in the earth crust, Conc. of ref. PTE in earth crust is the concentration of reference PTE in the earth crust. In this study, Fe was employed as the reference element for normalization synonymous (Nwosu *et al.*, 2021).

Human Health Risk Assessment

Average daily dose (D), non-cancer and cancer risk on exposure to PTE in indoor dust via ingestion, inhalation through mouth or nose, and dermal adsorption of dust particulates was evaluated according to the methods of Olujimi *et al.* (2015), Iwegbue *et al.* (2018) and Famuyiwa *et al.* (2018). The methods were computed using equations 3-8.

$$\text{DIng} = \text{Conc. of PTE x}\left(\frac{IngR \times EF \times ED}{BW \times AT}\right) \text{ x } 10^{-6} \quad (3)$$

$$\text{DInh} = \text{Conc. of PTE x}\left(\frac{InhR \times EF \times ED}{PET \times BW \times AT}\right) \quad (4)$$

$$\text{DDerm} = \text{Conc. of PTE x}\left(\frac{SA \times DAF \times SAF \times EF \times ED}{BW \times AT}\right) \text{x } 10^{-6} \quad (5)$$

Where D is in mg/kg/day, Conc. of PTE is the concentration of PTE in dust (mg/kg), IngR (ingestion rate) is 200 mg/day for children and 100 mg/day for adult and IhR (inhalation rate) is 7.63 mg/day for children and 12.8 mg/day for adult, ED is the exposure duration (6 years for children and 30 years for Adults), and EF is the exposure frequency 350days/year for children and adult. BW is the average body weight (70 kg for adult and 15 kg for children) and AT is the average exposure time (non-carcinogens is ED × 365 days; carcinogens is 70 ×365 = 25,550 days). CF is the conversion factor (1x10^{-6} kg/ mg), SA is the exposed skin surface area (2800 cm^2 for children and 4340 cm^2 for adult), SAF is the skin adherence factor (0.2 mg/cm^2/d^1 for children and 0.7 mg/cm^2/d^1 for adult), DAF is the dermal absorption factor(0.001 for both children and adult) and PEF is the particle emission factor (1.36 x 10^9 m^3/kg for both children and adult).

$$\text{HQ} = \text{D} / \text{RfD} \quad (6)$$

$$\text{HI} = \sum \text{HQi} \quad (7)$$

$$\text{TCR} = \text{D} \times \text{CSf} \quad (8)$$

The non-carcinogenic risk expressed as the hazard quotient (HQ) was computed by dividing the values of D for individual PTE on each exposure route with their corresponding reference doses (RfD). Cancer risk due to prolonged exposure to

carcinogens was assessed by multiplying the D with the cancer slope factor (CSF). The interactions between some PTE may be synergistic (Xu *et al.*, 2011),therefore, it is anticipated that the risk of all the PTE is additive, which formed the premise for estimating the aggregate non-carcinogenic risk which is termed the hazard index (HI) and the summative carcinogenic risk referred to as the total Cancer Risk (TCR).The interpretation of the HI is that value of HI equal to or less than 1 indicates no adverse health effect while the value of HI greater than 1 indicates the probability of an adverse health effects. The greater the value of HI above 1, the greater the degree of concern (US EPA, 2002).

Generally, an excess carcinogenic risk of 10^{-6}, shows a probability of one chance in a million population of equally exposed persons of the risk of developing cancer, which is considered as the target cancer risk. The values below are considered to be negligible and acceptable while carcinogenic risk above 10^{-4} are considered significant and unacceptable (Iwegbue *et al.*, 2018; US EPA, 2013).

Data Management and Analysis

Data were analyzed using statistical package for social sciences version 21 to generate the mean and standard deviation, Microsoft Excel 2016 was use for calculating the degree of pollution and health risk assessment.

RESULT AND DISCUSSIONS

Concentration of PTE in Office dust

The concentration of PTE in dusts represented in Table 1, is in comparing to the UK environmental agency soil guideline value, Canada soil guideline value (CSGV) and Dutch intervention value (DIV) due to the unavailability of soil guideline values in Nigeria.

The concentration of Fe, Mn and Co from the study varied from 1380 -8450 mg/kg, 47.1 -160 mg/kg and4.76- 13.43 mg/kg with a mean of 4670 mg/kg, 93.5 mg/kg and 8.37 mg/kg respectively. The concentration of Fe in all samples were higher than 1000 mg/kg with the highest concentration recorded in sample A2 followed by sample A3. Mn concentration greater than 100 mg/kg was reported in 40% of the sample in the order of A2 > A3 > A1 > A7 (Table 1). The highest Co concentration was recorded in sample A1. The source of Co in the indoor dust are dust particulate from outdoor pollution. Mean Fe concentration (4670 mg/kg) was lower to the indoor dust studies from Saudi Arabia (8751 mg/kg), Malaysia (10800 mg/kg) and Southern-Nigeria (23,499 mg/kg) but higher than indoor dust study from Abeokuta (13.7 mg/kg) (table 2).Furthermore, Mean Mn concentration was lower to reports from studies in Sydney, Australia (220 mg/kg), Ottawa, Canada (267 mg/kg) and Jeddah, Saudi Arabia (391 mg/kg) (Table 2). While mean Co concentration from the study was similar indoor dust report of Jeddah, Saudi Arabia (8.2 mg/kg) and Ottawa, Canada (8.92 mg/kg), higher than the report from Abeokuta, Nigeria (4.21 mg/kg) and Istanbul, Turkey (5.0 mg/kg) but lower to the report from Southern, Nigeria (31.3 mg/kg) (Table 2).

The concentration of Pb and Zn from the study varied from 50.3 -347 mg/kg and 10.8 -472 mg/kg with a mean of 160 mg/kg and 185 mg/kg respectively. Lead and Zinc concentration in 40% and 20% of the samples were higher than the CSGV for Pb in dust (140 mg/kg) (Table 1). Lead toxicity caused by prolonged exposure to Pb affects the human gastro-intestinal tract and the central nervous system. Progressively, children exposure can specifically result in neuro-degradation and neural tube defect (Wani *et al.*, 2015) while Zn toxicity causes headaches, nausea, vomiting and diarrhea (Willoughby and Bowen, 2014). According to Li *et al.* (2011), paints pigments, batteries, roofing materials and electrical appliances in offices are zinc products. Therefore, zinc sources in the dust are traceable to wall paints and roofing sheets since the area possess largely ancient buildings with zinc roofing sheets. Mean Pb concentration (160 mg/kg) was higher than indoor dust studies from Abeokuta, Nigeria (27.6 mg/kg), Istanbul, Turkey (28.0 mg/kg) and Kathmandu, Nepal (65.3 mg/kg) but lower to the report from Ottawa, Canada (406 mg/kg), Xi'an, China (180.9 mg/kg) and Sydney, Australia (199 mg/kg) while mean Zn concentration was higher than the report from studies in Abeokuta, Nigeria (121 mg/kg) but lower to the reports from Ottawa, Canada (717 mg/kg), Istanbul, Turkey (832 mg/kg) and Jenka, Malaysia (2879 mg/kg) (Table 2).

The concentration of Cu from the study varied from 8.45 -95.5 mg/kg with a mean of 39.1 mg/kg. Cu concentration in all samples falls below the compared SGVs. The sources of Cu are from cables, various Cu-coated equipments in the offices. Mean Cu concentration (39.1 mg/kg) was lower than the CSGV (140 mg/kg) and DIV (190 mg/kg) for Cu in dust (Table 1). In comparison to previous studies, the mean concentration of Cu was lower than indoor dust studies from Jenka, Malaysia (97.4 mg/kg), Xi'an, China (70.8 mg/kg), Bushehr, Iran (234 mg/kg), Southern, Nigeria (233 mg/kg) and Ottawa, Canada (206 mg/kg) (Table 2).

The concentration of Cr from the study varied from 5.85 -37.9 mg/kg with a mean of 20.4 mg/kg. Highest Cr concentration was recorded in sample A7 followed by sampleA6. Cr source are colorant from wall paints in offices (Mohanty and Kumar, 2013). Concentration of Cr in all sample were lower than the UK (200 mg/kg) and DIV (380 mg/kg) soil guideline value. Mean Cr concentration was lower than reported from indoor dust studies in Abeokuta, Nigeria (41.8 mg/kg), Bushehr, Iran (49.0 mg/kg), Istanbul, Turkey (55.0 mg/kg), Ottawa, Canada (86.7 mg/kg), Kathmandu, Nepal (158 mg/kg) and Southern, Nigeria (27.1 mg/kg) (Table 2).

The concentration of Cd from the study varied from 2.47 -7.25 mg/kg with a mean of 4.98 mg/kg. Highest concentration of Cd was recorded in sample A10, although all sample were lower than the UK (150 mg/kg), CSGV (22 mg/kg) and DIV (12 mg/kg) for Cd in dust. The primary source of Cd in the dust are infiltration of automobile exhaust and contaminated particles. Mean Cd concentration from the study was similar to the studies from Ottawa, Canada (6.46 mg/kg), USA (4.3 mg/kg) and Bushehr, Iran (3.1 mg/kg); higher than the report from Jeddah, Saudi Arabia (2.09 mg/kg) and Istanbul, Turkey (0.84 mg/kg) but lower extensively to the report from Southern-Nigeria (32.0 mg/kg) and Abeokuta, Nigeria (855 mg/kg) (Table 2).

Table 1: PTE level in selected office dusts

Sample	Fe	Pb	Cu	Cr	Zn	Co	Cd	Mn
A1	4250	226	35.0	7.66	408	13.4	4.81	125
A2	8450	75.5	47.5	24.5	142	8.25	6.69	160
A3	8190	347	95.5	16.3	18.8	9.20	4.96	157
A4	3530	50.3	48.5	18.3	15.2	7.25	2.84	47.1
A5	3650	223	15.0	5.85	68.6	5.05	5.27	63.2
A6	2930	129	17.7	31.8	245	8.85	2.80	63.8
A7	4650	93.5	46.8	37.9	273	9.60	5.55	107
A8	1380	273	8.45	21.3	10.8	4.76	7.16	84.2
A9	4450	106	28.8	17.8	472	7.33	2.47	64.4
A10	5240	76.8	47.5	22.7	199	10.4	7.25	63.8
Min	1380	50.3	8.45	5.85	10.8	4.76	2.47	47.1
Max	8450	347	95.5	37.9	472	13.43	7.25	160
Mean	4670	160	39.1	20.4	185	8.37	4.98	93.5
Std. Dev.	2200	100	24.9	9.76	165	2.53	1.79	41.3
UK, 2013	-	450	-	200	-	-	150	-
CSGV, 2009	-	140	I40	-	360	-	22	-
DIV (Qing *et al.,* 2015)	-	530	190	380	750	-	12	-

Table 2: Comparison of PTE level in selected office dusts with other studies

Location	Fe	Pb	Cu	Cr	Zn	Co	Cd	Mn
Current study(Adodo-Ota)	4670	160	39.1	20.4	185	8.37	4.98	93.5
Kathmandu, Nepal (Bhandari *et al.,* 2021)	-	65.3	-	158	-	-	0.89	-
Southern, Nigeria (Iwegbue *et al.,* 2019)	23500	144	233	27.1	825	31.3	32.0	541
Jeddah, Saudi Arabia (Mansour *et al.,* 2019)	8751	121	-	87.9	343	8.2	2.09	391
Sydney, Australia (Israel *et al.,* 2019)	-	199	272	90	1876	-	-	220
Jenka, Malaysia (Sulaiman *et al.,* 2017)	10800	1737	97.4	-	2879	-	-	-
Bushehr, Iran (Ardashiri and Hashem, 2017)	-	53.0	234	49.0	1423	-	3.1	-
Abeokuta, Nigeria (Olujimi *et al.,* 2015)	13.7	27.6	59.4	41.8	121	4.21	855	328
Xi'an, China (Chen *et al.,* 2014)	-	180.9	70.8	149.2	461.5	-	-	-
Ottawa, Canada (Rasmussen *et al.,* 2013)	-	406	206	86.7	717	8.92	6.46	267
Istanbul, Turkey (Kurt-Karakus, 2012)	-	28.0	156	55	832	5.0	0.84	136
USA (Zota *et al.,* 2011)	-	109	-	-	876	-	4.3	143

Geo-accumulation index (I-geo) and Enrichment Factor (EF)

The I-geo and EF value of PTEs in indoor dust are presented in Table 3, I-geo indicated that the dust was moderately polluted with Cd, unpolluted to moderately polluted with Pb and Zn and practically unpolluted with other PTEs (Fe, Cr, Mn, Co and Cu). The value for Cd was greater than 1 suggesting an anthropogenic source. Enrichment Factor for the PTEs revealed that the dust contained an extremely high enrichment of Cd and Pb, severe enrichment of Zn and Cu, a moderate enrichment of Cr and Co and minimal enrichment with Fe and Mn. The EF value for Cd, Pb and Zn were greater than 10 suggesting an anthropogenic source while Cu, Co, Mn and Cr were less than 10 but higher than 1, suggesting a partial emergence from anthropogenic and natural sources.

Table 3: I-geo and EF in selected office dusts

PTE	Mean	I-geo	EF	Degree of Pollution (Famuyiwa *et al.*, 2018)	
Fe	4670	-1.18	1	Practically unpolluted	Minimal enrichment
Pb	160	0.73	80.9	Unpolluted to moderated polluted	Extremely high enrichment
Cr	20.4	-0.82	2.30	Practically unpolluted	Moderate enrichment
Zn	185	0.11	19.7	Unpolluted to moderated polluted	Severe enrichment
Mn	93.5	-1.13	1.11	Practically unpolluted	Minimal enrichment
Co	8.37	-0.53	4.45	Practically unpolluted	Moderate enrichment
Cu	39.1	-0.24	8.78	Practically unpolluted	Severe enrichment
Cd	4.98	1.04	168	Moderately polluted	Extremely high enrichment

Health Risk Assessment

Average Daily Dose

The average daily dose (D) of PTEs is represented in Table 4, the D of PTEs in the indoor dust reveals the dosage in the following order ingestion > dermal > inhalation in children and adults, pointing ingestion has the major pathway of exposure. More so, it also indicated that the children are venerable to exposure than the adult. The exposure to individual PTE in the dust is in the order of Fe > Zn > Pb > Mn > Cu > Cr > Co > Cd for children and adults in the environment.

Table 4: Average Daily Dose of PTE in dust

Human	Exposure	Fe	Pb	Cu	Cr	Zn	Co	Cd	Mn
Children	Ding	3.07E-01	1.05E-02	2.57E-03	1.34E-03	1.22E-02	5.50E-04	3.27E-04	6.15E-03
	Dinh	1.17E-08	4.00E-10	9.77E-11	5.10E-11	4.62E-10	2.09E-11	1.24E-11	2.34E-10
	Dderm	8.60E-04	2.95E-05	7.20E-06	3.76E-06	3.41E-05	1.54E-06	9.17E-07	1.72E-05
Adult	Ding	3.29E-02	1.13E-03	2.75E-04	1.44E-04	1.30E-03	5.90E-05	3.51E-05	6.59E-04
	Dinh	6.58E-09	2.25E-10	5.51E-11	2.87E-11	2.61E-10	1.18E-11	7.02E-12	1.32E-10
	Dderm	7.60E-04	2.60E-05	6.36E-06	3.32E-06	3.01E-05	1.36E-06	8.10E-07	1.52E-05

Non-Carcinogenic and Carcinogenic Risk

Carcinogenic and non-carcinogenic risk associated with PTE in indoor presented in Tables 5, revealed that the HI value for PTEs were below 1, suggesting a non-adverse non-carcinogenic risk for the occupants. However, the value for Pb and Co accounting for 52% and 31% respectively for the overall non cancer risk in children (Fig. 1) were closer to 1, indicating a concern. The total carcinogenic risk (TCR) associated with PTE exposure in the indoor dustshowed that adult have a one in a million chance (37% Cr, 63% Pb) of developing cancer on an equally prolonged exposure to the dust, whereas, children are free from Pb (12%) carcinogenicity but possess the chance of developing cancer on exposure to Cr (88%) in the indoor dust (Fig. 2).

Table 5: Cancer and Non-Cancer Risk

	IngRfd	InhRfd	DermRfd	HQ_{ing}	HQ_{inh}	HQ_{derm}	$\sum HQ_i=HI$	$\sum CR_i=TCR$
				Children				
Pb	3.50E-03	3.52E-03	5.25E–04	3.00E+00	1.14E-07	5.62E-02	3.06E+00	7.66E-06
Cr	3.00E-03	2.86E-05	6.00E-05	4.47E-01	1.78E-06	6.27E-02	5.09E-01	5.75E-05
Zn	3.00E-01	3.00E-01	6.00E-02	4.07E-02	1.54E-09	5.68E-08	4.07E-02	
Mn	1.40E-01	5.00E-02	1.40E-01	4.71E-03	2.64E-09	1.09E-04	4.82E-03	
Co	3.00E-04	5.70E-06	3.00E-04	1.83E+00	3.67E-06	5.13E-03	1.84E+00	
Cu	4.00E-02	4.02E-02	1.20E-02	6.43E-02	2.44E-09	6.00E-04	6.49E-02	
Cd	1.00E-03	1.00E-02	2.50E-05	3.27E-01	1.24E-09	3.67E-02	3.64E-01	
				Adults				
Pb	3.50E-03	3.52E-03	5.25E–04	3.71E-02	6.39E-08	4.95E-02	8.67E-02	4.12E-05
Cr	3.00E-03	2.86E-05	6.00E-05	4.80E-02	1.00E-06	5.53E-02	1.03E-01	2.46E-05
Zn	3.00E-01	3.00E-01	6.00E-02	4.33E-03	8.70E-10	5.02E-08	4.33E-03	
Mn	1.40E-01	5.00E-02	1.40E-01	1.31E-02	4.68E-09	1.23E-04	1.33E-02	
Co	3.00E-04	5.70E-06	3.00E-04	1.97E-01	2.07E-06	4.53E-03	2.01E-01	
Cu	4.00E-02	4.02E-02	1.20E-02	6.88E-03	1.38E-09	5.30E-04	7.41E-03	
Cd	1.00E-03	1.00E-02	2.50E-05	3.51E-02	7.02E-10	3.24E-02	6.75E-02	

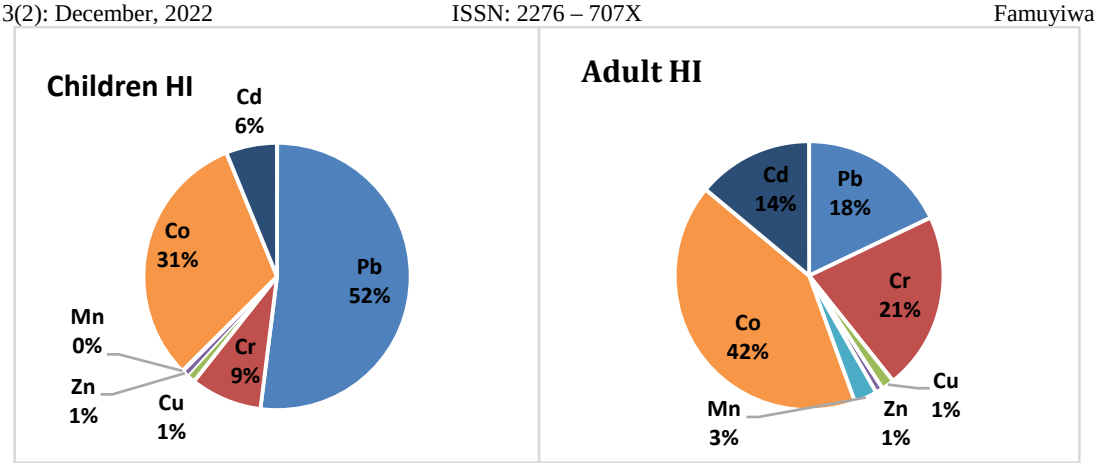

Fig. 1: HI Percentage for each PTE to the overall non-cancer risks in children and adults

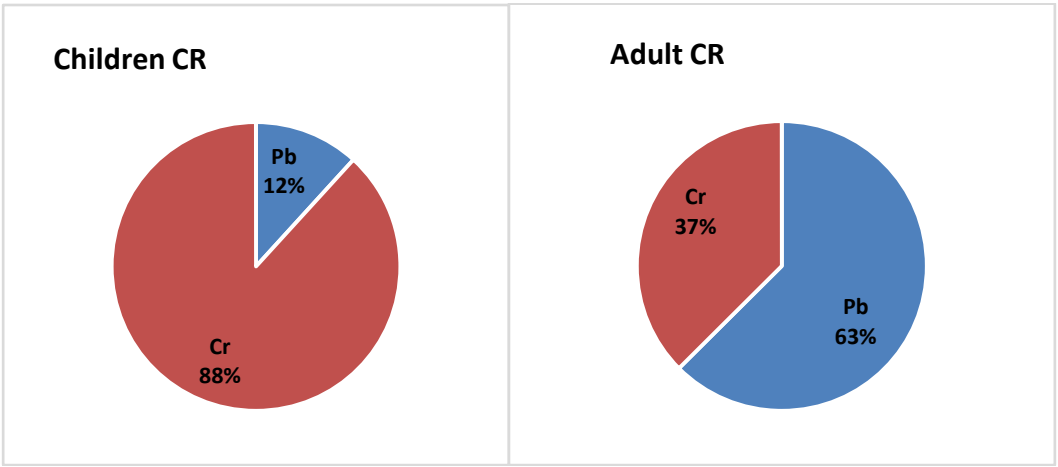

Fig. 2: Cr Percentage for each PTE to the overall cancer risks in children and adults

CONCLUSION

The examined indoor dust was observed to be polluted with some toxic elements which was traced to anthropogenic sources. More so, a lifetime exposure to the dust might put the occupants at a chance of developing cancer. It is therefore, recommended that a constant wet cleaning and renovation of the buildings should be considered while citing of vehicle and generator sets in the surroundings should be monitored.

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