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Elemental Analysis, Pollution Indexing and human health implications of dusts trapped in air conditioner filters in a University environment

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ABSTRACT

Pollution caused by heavy metals from various anthropogenic sources has become a global concern. This research assessed the concentration and human toxicological implication of potentially toxic element (PTE). Fugitive dusts isolated from air condition filters were collected from different locations within Babcock University, Ilisan Remo Campus, Ogun State, South Western Nigeria. A total of ten (10) composite samples were acid digested and analyzed using Atomic Absorption Spectrophotometer (AAS). The PTE concentration in the dust samples were below the soil guideline values for United Kingdom, Canada and Netherlands with exception to Zn. The PTE analyzed showed the general distribution pattern of Fe > Zn > Mn > Pb > Cu > Co > Cr > Cd. Enrichment factor and geoaccumulation index calculations revealed Cd and Zn were severely enriched in the dust samples. Human health risk assessment study indicated that ingestion was the major pathway for PTE exposure followed by dermal contact and inhalation in that order. Generally, the non-cancer contribution pattern for the PTE's hazard index was in the following order: Fe > Co > Cd >Mn> Zn >Pb> Cr > Cu. Fe exceeded the acceptable limit of 1 for non-cancer effects in both children and adult. This suggests that there is a possible susceptibility to Fe toxicity from the dusts. The range for all of all metals was within the acceptable limit of 1×10^{-6} to 1×10^{-4} and this indicates no probable cancer effects.

1. INTRODUCTION

Dust is a material that has largely been ignored as a significant source of heavy metal contamination in urban environments (Popoola et al., 2012). The composition of indoor dust varies from site to site depending on

the activities being carried out both within and outside a place (Siddique et al., 2011). Indoor dust is a repository for environmental pollutants such as heavy metals that may accumulate indoors and is an important pathway of exposure to metals for humans (Darus et al., 2012). People spend the majority of their time (around 80–90 percent) indoors in their homes, offices, workplaces, schools, and transportation vehicles and therefore, quality of the air at these places has a direct effect on our health (Darus et al., 2012; Sulaiman et al., 2017; Pan et al., 2017). Their accumulation within the tissue and internal organs of humans can affect the central nervous system and may lead to the promotion of other diseases (Zheng et al., 2010). Dust makes a significant contribution to the pollution in urban environment and consists of vehicle exhaust, sinking particles in air, house dust, soil dust and aerosols that are carried by air and water. More importantly, elevated indoor heavy metals concentrations could be attributed to outdoor sources such as heavily traffic roads and proximity to industrial sites (Carleton et al., 2018; Praveen et al., 2018; Mahfouz et al., 2019).

Internal contributions of PTE in indoor dusts include combustion processes such as heating, cooking, and smoking cigarettes. Others are abrasion, eroding wall paints, or burning incense sticks various materials such as paper, carpet, clothing, use of beauty products, electric appliances and chemical products, pets, etc (Turner 2011; Gohain and Deka, 2020)

The waste from power stations utilizing fossil fuels such as coal, mineral processing industries, refineries, mines and brickworks may also emit toxic elements to the atmosphere and diffuse into our homes and workplaces. Contrary to outdoor air, indoor air is confined within a small space or circulated by fans or air conditioner units in warm/hot climates thereby exacerbating the hazards. In Nigeria, air conditioners (ACs) are used extensively in residential and commercial buildings, schools, hospitals etc., especially during summer season of the year.

Air conditioning (AC) is widely used as an effective means of controlling heat and to keep the indoor air quality within safe levels, since air pollutants such as particulate matter can be captured on the AC filter (Alghamdi et al. 2019). The analysis of dust particles collected from AC filters could provide useful information about indoor air quality of a place. Indoor activities have been discovered to have potential health hazards associated with the airborne composition and this may get into human body through three main exposure routes: inhalation, ingestion, and dermal contact. Indoor dust containing potentially toxic elements such as Cd, Pb, Zn, Cr etc have been reported to cause cardio injury, cancer and non-cancer related diseases. Because of their persistent existence, high toxicity, and negative health effects, heavy metals found in indoor settled dust and their associated health risks must be assessed. Students and staff are university's most important stakeholders. They spend the majority of their time indoors in a residential higher educational institution's various settings such as classrooms, laboratories, libraries, hostels, eateries, and so on). Only a few studies have been conducted to investigate the PTE composition in university campus indoor dust, especially in tropical environments such as Nigeria. In the past, heavy metals and other toxic pollutants have been studied extensively in developed and other developing countries (Rasmussen et al., 2013; Gohain and Deka 2020; Sulaiman et al., 2017; Alghamdi et al., 2019). However, there is limited data on indoor dust in Nigeria and/or the presence of heavy metals in AC filter dust in a University environment, hence, the need for this study. The aim of this study was to investigate the levels and human toxicological implications of PTE in AC filter dusts at Babcock University, Ogun State, Southwestern Nigeria.

2. MATERIALS AND METHODS

2.1. Study Area

Babcock University is a private Nigerian University owned and operated by Seventh Day Adventist church of Nigeria. It is located in Ilisan-Remo in Ogun state, Southwestern Nigeria and it is equidistant between Lagos and Ibadan. It operates about 10 faculties and 30 departments. The campus is located in a rural

suburban area away from commercial and industrial activity. The university is surrounded by villages and rural areas. It was established in 1999 and it is one of the pioneer privately established universities in Nigeria.

2.2. Sampling, Sample Collection and Processing

AC dust samples were collected from ten (10) strategic locations within Babcock University cutting across the university's shopping mall, laboratories, classrooms, residential halls, and offices. These locations account for typical hazards anticipated in the problem statement of this study, considering the high volume of students' activities and staff offices. The geographical coordinates and description of the sampling sites are given in Table 1.

Table 1: Geographical coordinates and description of sampling sites

S/N	Coordinate	Sample name	Site description
1	Technologist Office (6º 53' 17''N, 3º 43' 22''E)	S1	Office of the laboratory Manager
2	Registry Lobby (6º 53' 20''N, 3º 43' 19''E)	S2	Location were student deals with registration and result issues
3	Babcock shopping mall (6º 53' 27''N, 3º 43' 14''E)	S3	Where students, staffs and visitors buys groceries and snacks
4	Biochemistry Laboratory (6º 53' 28''N, 3º 43' 17''E)	S4	Where students perform Biochemical practical's and experiments
5	Chemistry Laboratory (6º 53' 17''N, 3º 43' 22''E)	S5	Where students perform chemical practical's and experiments
6	Crystal Hall (6º 53' 33''N, 3º 43' 39''E)	S6	Residence hostel for students
7	Cafeteria (6º 53' 30''N, 3º 43' 37''E)	S7	Student dining Hall
8	Bursary (6º 53' 25''N, 3º 43' 24''E)	S8	Payment of tuition and other charges
9	Office (6º 53' 39''N, 3º 43' 18''E)	S9	Lecturer's office
10	Microbiology Lab (6º 53' 16''N, 3º 43' 23''E)	S10	Where students perform microbial practical's and experiments

The samples were collected from ACs which were split ACs located 8-10 feet above ground level. Each AC filter chamber was opened and the filter gently removed and dusted to collect the dust particles. About 3-4 g of dust was collected per AC and samples were bulked together (4 to 5 samples) to make a composite sample at each location. The dusts were then placed inside clean plastic tubes for storage. Samples were air-dried until moisture free and the dried samples were crushed and were further kept in different polyethylene sampling bags and labelled accordingly.

2.3. Heavy Metal Analysis

To evaluate the degree of heavy metals contamination in the dust, aqua-regia [matrix concentration of 1 nitric acid (HNO_3):3 hydrochloric acid (HCl)] was employed for digestion process. Digestion flasks for each of the dust samples were oven dried at 35 ºC for 15 minutes. One gram of each dust sample was transferred into well labelled and the oven dried digestion flasks and 20 mL of aqua-regia was added to each flask. The mixture was gently stirred to make a homogenous mixture and heated subsequently to about 95ºC (in a fume cupboard) until the sample evaporated to about 15 mL. The samples were later cooled, filtered and diluted with distilled water to 50 mL. The diluted samples were then collected into sample vials and labelled for metal analysis using Atomic Absorption Spectrophotometer (iCE3000 series), Thermo Fisher Scientific, Massachusetts, USA.

2.4 Pollution Assessment Methods

2.4.1. Geo-accumulation

The assessment of soil or sediment enrichment can be carried out in many ways. The most common ones are the index of geoaccumulation (Igeo) and enrichment factors (EF) (Lu et al., 2014. In this work, the (Igeo)

and (EF) were applied to assess heavy metals (Cr, Cu, Mn, Ni, Pb and Zn) distribution and contamination in the dust particles. A quantitative measure of the extent of metal pollution in the studied soil was calculated using the geoaccumulation index proposed by Muller (1969). This index (Igeo) of heavy metal is calculated by computing the base 2 logarithm of the measured total concentration of the metal over its background concentration using the following mathematical relation (Ntekim et al., 1993):

$$\text{Igeo} = \log_2\left[{}^{C_n}\!/_{1.5 \times Bn}\right] \quad (1)$$

Where:

Cn is the measured total concentration of the element n in the mud grain size fraction of sediment, Bn is the average (crustal) concentration of element n in shale (background) and 1.5 is the factor compensating the background data (correction factor) due to lithogenic effects.

Loska et al. (2004) gave the following interpretation for the geo-accumulation index:

- Igeo<0 = practically unpolluted
- 0<Igeo<1 = unpolluted to moderated polluted
- 1<Igeo<2 = moderately polluted
- 2<Igeo<3 = moderately to strongly polluted
- 3<Igeo<4=strongly polluted
- 4<Igeo<5= strongly to extremely polluted
- Igeo>5 = extremely polluted

2.4.2. Enrichment factor

Enrichment factor (EF) has been employed for the assessment of contamination in various environmental media by several researchers (Caspah et al., 2016; Carleton et al., 2019). Its version adapted to assess the contamination of various environmental media is as follows:

$$\text{EF} = \frac{{}^{C_n}\!/_{C_{\text{ref Sample}}}}{{}^{B_n}\!/_{B_{\text{ref background}}}} \quad (2)$$

Where:

C_n = Concentration of the examined element in sample
C_{ref} = Concentration of reference element in sample
B_n = Background concentration of examined element
B_{ref} = Background concentration of examined element

The contamination categories are recognized on the basis of the enrichment factor (Manno et al., 2006):

- EF<2 indicates deficiency to minimal enrichment
- EF = 2-5 moderate enrichment
- EF = 5-20 severe enrichment
- EF = 20-40 very high enrichment
- EF>40 extremely high enrichment

2.5. Health Risk Assessment

The potential health risk due to human exposure to heavy metals from indoor dust through inhalation (via mouth and nose), dermal contact and ingestion pathways was calculated according to the approach of previous researchers (Zheng et al., 2010; USEPA 2018; Song et al., 2019). Exposure calculation for daily estimation was achieved using the following equations:

$$D_{ing} = C \times \left[\frac{IngR \times EF \times ED}{BW \times AT}\right] \times 10^{-6} \quad (3)$$

$$D_{inh} = C \times \left[\frac{InhR \times EF \times ED}{PEF \times BW \times AT}\right] \quad (4)$$

$$D_{dermal} = C \times \left[\frac{SL \times SA \times ABS \times EF \times ED}{BW \times AT}\right] \times 10^{-6} \quad (5)$$

Where D (mg kg^{-1} day^{-1}) is the dose contacted through ingestion (D_{ing}), inhalation (D_{inh}) and dermal contact (D_{dermal}). Hazard index (HI) method and cancer risk method were used to assess the health risk due to human exposure to heavy metals from indoor dust. Before calculating HI, a hazard quotient (HQ) based on non-cancer toxic risk was calculated for individual metals according to Equation 6 (Famuyiwa et al., 2019). Details of each parameter used in computing different exposure pathways is shown in Table 2.

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

Table 2: Exposure parameters used for the health risk assessment through different exposure pathways

Parameter	Unit	Child	Adult	References
Body weight (*BW*)	kg	15	70	USEPA, 1989
Exposure frequency (*EF*)	days/year	180	365	USEPA, 1989
Exposure duration (*ED*)	years	6	24	USEPA, 2001
Ingestion rate (*IngR*)	mg/day	20	200	USEPA, 2001
Inhalation rate (*InhR*)	m^3/day	7.63	20	USEPA, 2001
Skin surface area (*SA*)	cm^2	2800	3300	Hu *et al.,* 2012
Soil adherence factor (*AF*)	mg/cm^2	0.2	0.7	Hu *et al.,* 2012
Dermal absorption factor (*ABS*)	none	0.1	0.1	Hu *et al.,* 2012
Particulate emission factor (*PEF*)	m^3/kg	1.36 X 10^9	1.36 X 10^9	Hu *et al.,* 2012
Conversion factor (*CF*)	kg/mg	10^{-6}	10^{-6}	USEPA, 2001
Average time (*AT*)	days	25550	2555 0	Hu *et al.,* 2012

In order to assess overall potential of non-carcinogenic effects posed by more than one PTE, the calculated values of HQ for each metal were summed (Equation 7), which expressed the hazard index (HI) (USEPA 1989).

$$HI = \sum (HQ) \quad (7)$$

To interpret the results of HQ and HI, values greater than 1 indicate that there is a chance for non-carcinogenic effects, and hazard risk values of less than one indicate that there is no significant risk for non-carcinogenic health effects (USEPA 1989, 1991, 2004). The carcinogenic risks that range between 10^{-4} and 10^{-6} are considered to be acceptable (USEPA, 1991).

3. RESULT AND DISCUSSION

3.1. Concentration of Heavy Metals

The average concentration of Cd, Cu, Cr, Pb, Co, Fe, Mn and Zn were 6.12, 44.8, 17.4, 105, 26.3, 14578, 201 and 858 mg/kg respectively (Table 3). Because soil guideline values (SGVs) are yet to be established in Nigeria, values from UK, Canada and Netherlands were employed for this current study. While soil guideline values are not available for Fe, Mn and Co, successive measurements for Cd, Cu and Cr were all below the SGVs (Table 3). About 70% of the samples (S1, S2, S3, S4, S8, S9 and S10) exceeded the SGV for Canada and 30% (S5, S6 and S7) exceeded the Dutch intervention value for Zn. Iron and manganese are essential components of soil minerals and are found in the earth's crust. All of the Fe and Mn concentrations dropped below the earth's crust and continental shale values, respectively, and were within normal soil concentration ranges.

Table 3: Concentration of potentially toxic elements in dust samples

	Cu	Cd	Cr	Pb	Co	Zn	Mn	Fe
S1	70.3	13.70	25.7	258	54.9	2515	351	20030
S2	64.3	6.65	37.0	174	51.7	1377	383	20028
S3	84.2	4.75	10.3	105	48.2	633	137	4945
S4	27.3	4.95	12.8	60.1	11.7	391	129	11255
S5	17.5	4.70	4.8	29.1	6.15	282	59.2	34937
S6	20.8	3.35	10.15	33.2	17.1	253	74.1	3995
S7	15.8	4.05	0.1	0.05	6.05	128	40.5	1452
S8	58.5	8.45	43.8	212	33.9	1657	491	25812
S9	44.2	5.15	21.15	89.9	10.5	659	187	11002
S10	45.6	5.50	8.5	90.1	22.8	685	163	8745
Average	44.8	6.12	17.4	105	26.3	858	201	14578
S.D.	*19.7*	*2.10*	*11.6*	*65.6*	*16.7*	*595*	*124*	*9443*
CLEA UK values[a]	-	150	200	450		-	-	-
Canadian soil guideline values[b]	140	22	-	140		360	-	
Dutch intervention values[c]	190	12	380	530		720	-	-
Earth's crust[d]	47	0.13	83	16	18	83	1000	46500
Continental shale[e]	45	0.3	45	20	19	95	840	47200

[a]Contaminated Land: Applications in Real Environments (CLAIRE) consortium, 2014a. SP1010 Final Project Report (Revision 2). Development of Category 4 Screening Levels for Assessment of Land Affected by Contamination. DEFRA R&P Project Report [a]

[b,c]https://www.esdat.net/environmental%20standards/canada/soil/rev_soil_summary_tbl_7.0_e.pdf

[d] V. Alekseenko, A. Alekseenko, The abundances of chemical elements in urban soils, Journal of Geochemical Exploration, 2014 Volume 147, Part B, Pages 245-249

[e] https://pubs.geoscienceworld.org/gsa/gsabulletin/article/72/2/175/5262/Distribution-of-the-Elements-in-Some-Major-Units

The general distribution pattern for PTE's was in the descending order of Fe > Zn > Mn > Pb > Cu > Co > Cr > Cd. The order reported in this study differs from the distribution pattern reported in other studies in Niger and Zamfara States in Nigeria (Tsafe et al., 2011). To further provide context for the data, elements in indoor house dusts from selected studies were recorded to provide additional background for the results (Table 4). Direct comparisons were restricted since these studies concentrate on household dust, and there are variations in sample preparation and interpretation. Element concentrations in the dust samples, on the other hand, were usually within the mean/geomean data recorded in previous studies. The concentration ranges for PTE in this study was found to be higher than those reported for Lagos (Popoola et al. 2012) and Niger Delta (Iwegbue et al., 2017) areas () in Nigeria but lower than those reported for Ogun State by Olujimi et al. (2015). Average Cu concentration in this study was found comparable to that reported for indoor dusts in Sri Serdang, Malaysia (Praveena et al., 2015). Similarly, reports of Zn concentration ranges in indoor dusts of Xian, China was fairly similar to the range measured for this study (Chen et. al 2013). However, average concentrations of Cd, Pb and Zn were higher than elements concentrations in indoor dusts of other Nigerians cities (Olujimi et al., 2015; Iwegbue et al. 2017; Popoola et al. 2012). On the average, the average concentrations of Cd, Cr, Cu, Mn, Pb and Zn obtained in this study were lower and in some cases multiple times lower than those reported for Xian, China (Chen et al., 2013), Selangor, Malaysia (Latif et al., 2013) and Canada (Rasmussen et al., 2013). The most probable reason may be connected to these countries long histories of industrialization and urbanization and consequently could have resulted in higher PTE concentrations measured in these studies.

3.2. Pollution Indexing

The geoaccumulation index (Igeo) for the eight elements investigated is presented in Table 4. The mean Igeo levels ranged from 0.0001 (Fe) to 5.8 (Cd) while the Igeo class ranged from uncontaminated or moderately contaminated to extremely contaminated.

Table 4: Pollution assessment of heavy metal in dust samples

Sites	Mean value	Geoaccumulation index		Enrichment factor		Pollution intensity
		I-geo value	I-geo grade	EF Value	EF Scale	
Cu	44.8	0.05	Igeo<0	2.1	2<EF>5	Moderate enrichment
Cd	6.12	5.81	Igeo>0	66.1	EF>40	Extremely high enrichment
Cr	17.4	0.03	Igeo<0	0.62	EF<2	Minimal enrichment
Pb	105	0.22	Igeo<0	17.0	5<EF>20	Severe enrichment
Co	26.3	0.20	Igeo<0	5.42	5<EF>20	Severe enrichment
Zn	858	0.07	Igeo<0	29.2	20<EF>40	Very high enrichment
Mn	202	0.06	Igeo<0	7.67	5<EF>20	Severe enrichment
Fe	14578	0.0001	Igeo<0	1.000	EF<2	Minimal enrichment

The mean enrichment factor value ranged from 0.62 (Cr) to 66.10 (Cd) as the class of the enrichment value ranged from minimal enrichment to extremely high enrichments. Cr and Fe were not enriched in the dust samples as the EF values obtained were 0.62 and 1.0 respectively. Cu was fairly or minimally enriched while Pb, Co and Mn showed severe enrichment. The EF value for Zn was 29.2 and this indicated very high enrichment, while Cd fell within the cadre of extremely high enrichment. The general pollution characteristics trend, based on the pollution assessment tools employed was in the descending order of Cd > Zn > Pb > Mn > Co > Cu > Fe > Cr. Cd and Pb are included in the International Agency for Research on Cancer (IARC) list of probable carcinogenic compounds and their anomalous enrichment in the AC filter dusts is of concern. The values of the pollution indices employed in this work is an indication of the University AC dust contamination capacity.

3.3. Potential Ecological Risk Index

The potential ecological risks assessments are presented in Table 5. According to Hakanson (1980) risk index rating, all the potentially toxic elements evaluated in this study ranged from low ecological risks to high ecological risks. The risk index results showed 40% of the sampling locations moderate (S4, S5, S6, S7) and appreciable ecological risks (S2, S3, S9, S10) respectively while only 20% showed high ecological risks (S1 and S8). Cadmium appeared to be the key influencing or contributory factor to risk index value (the most enriched) when compared to other metals studied and the lowest is Cr. In terms of the potential ecological risk indices of the eight individual metals, the potential ecological risk arrayed was in the descending order of E_R (Cd) > E_R(Pb) > E_R(Zn) > E_R(Cu) > E_R(Mn) > E_R(Cr).

Table 5: Potentially ecological risk assessment of elements in dust samples

Sites	Cu	Cd	Cr	Pb	Zn	Mn	PER	PER-Grade
S1	5.02	137	0.86	64.4	26.5	4.13	238	High ecological risk
S2	4.60	66.5	1.23	43.4	14.5	4.50	135	Appreciable ecological risk
S3	6.01	47.5	0.34	26.3	6.66	1.61	88.1	Appreciable ecological risk
S4	1.95	49.5	0.43	15.01	4.12	1.52	72.5	Moderate ecological risk
S5	1.25	47.0	0.16	7.29	2.97	0.70	59.3	Moderate ecological risk
S6	1.49	33.5	0.34	8.29	2.66	0.87	47.1	Moderate ecological risk
S7	1.13	40.5	0.00	0.013	1.35	0.48	43.5	Moderate ecological risk
S8	4.18	84.5	1.46	53.1	17.5	5.78	166	High ecological risk
S9	3.16	51.5	0.71	22.5	6.94	2.21	86.9	Appreciable ecological risk
S10	3.25	55.0	0.28	22.5	7.22	1.92	90.1	Appreciable ecological risk

3.4. Human Health Risks Assessment

Reference doses employed in this study, average daily dose and the results of the human health risk evaluation of the carcinogenic and non-carcinogenic effect of heavy metals in children and adults using the

mean value of the metals are presented in Tables 6, 7, and 8 respectively. For the non-cancer effects for adults, ingestion was the major route of exposure followed by dermal contact and inhalation in that order.

Table 6: Reference doses (*RfD*) in (mg/kg-day) and cancer slope factors (*CSF*) for the different heavy metals

PTE	Ing*RfD*	Dermal *RfD*	Inh*RfD*	Ref	Ing*CSF*	Dermal *CSF*	Inh*CSF*	Ref
Mn	1.4×10^{-4}	1.40×10^{-1}	5.0×10^{-2}	Olujimi et al., 2015	-	-	-	
Pb	3.0×10^{-1}	3.5×10^{-3}		Olujimi et al., 2015	8.5×10^{-3}	-	4.2×10^{-2}	Caspah et al., 2016
Cd	1.0×10^{-3}	2.5×10^{-5}	1.0×10^{-2}	Olujimi et al., 2015	-	-	6.3×10^{1}	Caspah et al., 2016
Fe	3.0×10^{-3}	3.0×10^{-3}	4.5×10^{-2}	Famuyiwa et al., 2018	-	-	-	
Ni	1.10×10^{-2}	4.4×10^{-4}	5.91×10^{-5}	Olujimi et al., 2015	-	-	-	
Cu	4.0×10^{-2}	4.0×10^{-2}	-	Olujimi et al., 2015	-	-	-	
Co	3.0×10^{-4}	1.13×10^{-3}	3.0×10^{-4}		2.0×10^{-2}	5.0×10^{-3}	-	
Zn	3.0×10^{-1}	3.0×10^{-1}	-	Olujimi et al., 2015	-	-	-	

Table 7: Daily averaging dose

	Parameters	Cu	Cd	Cr	Pb	Co	Zn	Mn	Fe
Children	D_{ing}	3.69×10^{-5}	5.03×10^{-6}	1.43×10^{-5}	8.64×10^{-5}	2.16×10^{-5}	7.05×10^{-4}	1.66×10^{-4}	1.20×10^{-2}
	D_{inh}	3.47×10^{-9}	4.74×10^{-10}	1.35×10^{-9}	8.13×10^{-9}	2.04×10^{-9}	6.64×10^{-8}	1.56×10^{-8}	1.13×10^{-6}
	D_{dermal}	2.06×10^{-7}	2.82×10^{-8}	8.02×10^{-8}	4.84×10^{-7}	1.21×10^{-7}	3.95×10^{-6}	9.28×10^{-7}	6.71×10^{-5}
Adult	D_{ing}	1.23×10^{-4}	1.68×10^{-5}	4.77×10^{-5}	2.88×10^{-4}	7.21×10^{-5}	2.35×10^{-3}	5.52×10^{-4}	3.99×10^{-2}
	D_{inh}	5.78×10^{-9}	7.9×10^{-10}	2.25×10^{-9}	1.35×10^{-8}	3.39×10^{-9}	1.11×10^{-7}	2.6×10^{-8}	1.88×10^{-6}
	D_{dermal}	1.87×10^{-6}	2.55×10^{-7}	7.25×10^{-7}	4.37×10^{-6}	1.09×10^{-6}	3.57×10^{-5}	8.39×10^{-6}	6.07×10^{-4}

Table 8: Carcinogenic and non-carcinogenic risks of heavy metals in dust samples

	HQ_{ing}	HQ_{inh}	HQ_{dermal}	HI	R-ing	R-inh	R-dermal	CR
				Adult				
Cu	3.08×10^{-3}		4.7×10^{-9}	4.68×10^{-9}				
Cd	1.68×10^{-2}	7.9×10^{-12}	1.0×10^{-12}	1.68×10^{-2}		2.71×10^{-8}		2.71×10^{-8}
Cr	1.59×10^{-8}	2.3×10^{-10}	9.6×10^{-13}	1.61×10^{-8}	8.20×10^{-6}	3.85×10^{-10}	1.25×10^{-7}	8.33×10^{-6}
Pb	9.6×10^{-4}		1.3×10^{-9}	9.6×10^{-4}	8.39×10^{-7}	1.95×10^{-10}		8.39×10^{-7}
Co	2.4×10^{-1}	3.01×10^{-6}	3.6×10^{-3}	2.44×10^{-1}	4.94×10^{-7}	5.80×10^{-12}		4.94×10^{-7}
Zn	7.83×10^{-3}		1.2×10^{-6}	7.83×10^{-3}				
Mn	3.94×10^{-3}	5.2×10^{-7}	5.9×10^{-7}	3.94×10^{-3}				
Fe	1.33×10^{1}	6.3×10^{-4}	1.4×10^{-2}	1.33×10^{1}				
				Children				
Cu	9.22×10^{-4}		5.2×10^{-10}	9.22×10^{-4}				
Cd	5.03×10^{-3}	4.7×10^{-12}	1.1×10^{-13}	5.03×10^{-3}		1.62×10^{-8}		1.62×10^{-8}
Cr	4.77×10^{-9}	1.4×10^{-10}	1.1×10^{-13}	4.91×10^{-9}	2.46×10^{-6}	2.31×10^{-8}	1.38×10^{-8}	2.47×10^{-6}
Pb	2.88×10^{-4}		1.4×10^{-10}	2.88×10^{-4}	2.52×10^{-7}	1.17×10^{-10}		2.52×10^{-7}
Co	7.20×10^{-2}	1.8×10^{-6}	4.0×10^{-4}	7.24×10^{-2}	1.48×10^{-7}	3.49×10^{-12}		1.48×10^{-7}
Zn	2.35×10^{-3}		1.3×10^{-7}	2.35×10^{-3}				
Mn	1.19×10^{-3}	3.1×10^{-7}	6.6×10^{-8}	1.19×10^{-3}				
Fe	4.00×10^{1}	3.8×10^{-4}	1.5×10^{-3}	4.00×10^{1}				

The non-cancer distribution pattern for PTE hazard index was: Co > Fe > Cd > Cu >Mn> Zn >Pb> Cr. Furthermore, the major contributor to the hazard influence of the PTE was Co while the least contributor was Cr (Figure 1). Similarly, in children, the exact same non-cancer distribution pattern was obtained Co > Fe > Cd > Cu >Mn> Zn >Pb> Cr. Iron exceeded the acceptable limit of 1 for non-cancer effects in children. This suggests that these metals could cause or contribute to non-cancer effects in both adults and children; however, children are more susceptible to these non-cancer effects because of the vulnerability of their developing nervous system.This finding is similar to the trend reported by Zheng et al. (2010). However, the

values reported in this study were higher than findings reported by other researchers (Abrahim and Parker, 2008; Shi et al., 2011; Hu et al., 2012; Olujimi et al., 2015; Iwegbue et al., 2017). The sum for all hazard quotients of PTE on individual and collective basis revealed that the values were less than 1 with the exception of Fe. Fe was the PTE of concern considering the outcome of non-carcinogenic risks calculations. This is an indication of potential side effects from Fe toxicity as the general population of the University concern be affected depending on conditions and particular body chemistries.

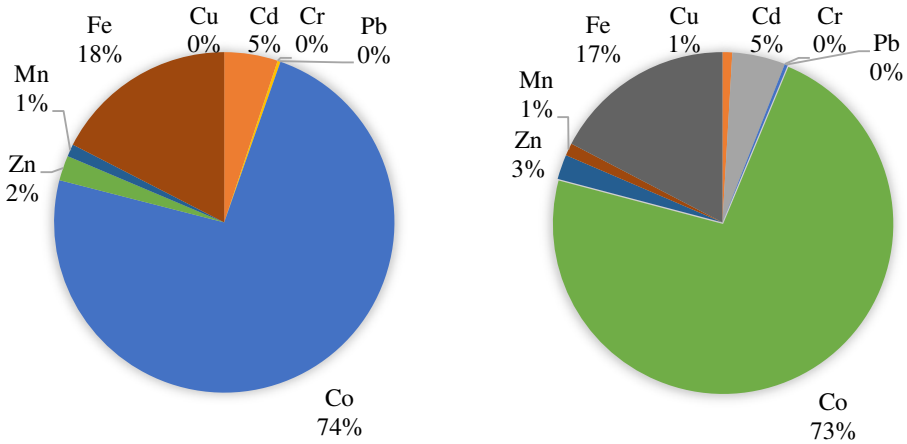

Figure 1: Contributions of PTE to total non-carcinogenic risks in children (left) and adult (right)

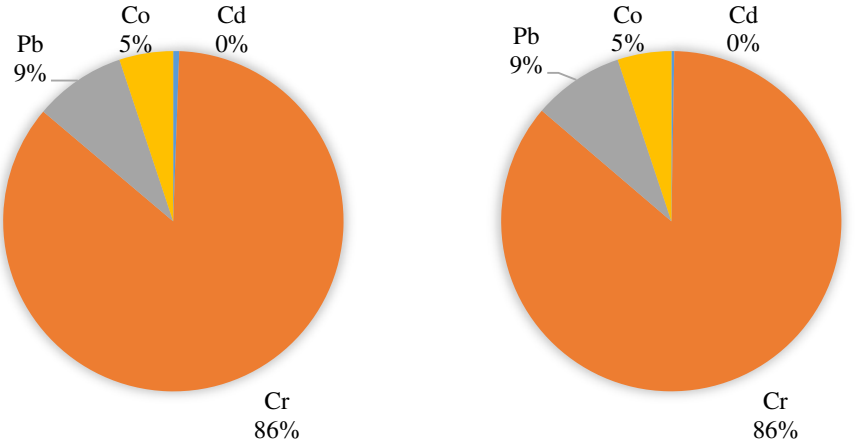

Figure 2: Contributions of PTE to total carcinogenic risks in children (left) and adult (right)

The carcinogenic risk (CR) for Cd, Cr, Co and Pb were considered as presented in Figure 2, as their respective slope factors are available in literature. The cancer risk assessment showed that Cd, Co, Ni and Pb were generally below the acceptable limit range of 1.0×10^{-4} to 1×10^{-6} and these results indicated that carcinogenic risks are insignificant over a lifetime. The overall cancer risk ($\sum$CR) (9.69×10^{-6}) for adult and (2.89×10^{-6}) for children of all sampled locations indicates that there is no probable cancer effect due to exposure to these elements. The elements distribution pattern reported in this study is similar to previous works on indoor dusts as reported by Shi et al. (2011) and Olujimi et al. (2015). The cumulative percentage contribution of each element is presented in Figure 1 and 2. Chromium played a prominent effect as it accounted for 86% of the cumulative carcinogenic risks for both children and adult.

4. CONCLUSION

The study found concentrations of PTE to be below soils guideline values except for Zn which exceeded the Canadian and Dutch intervention values at about 70%(S1, S2, S3, S4, S8, S9 and S10) of the sampling locations. The elements concentration showed the general distribution pattern Fe > Zn > Mn > Pb > Cu > Co > Cr > Cd. The PTE investigated were significantly enriched in the dust samples except for Cr and Fe which showed minimal enrichment. There were fair agreements between the EF and Igeo results in the current study. Potential ecological risk index results revealed 40% of the sampling locations showed appreciable (S2, S3, S9, S10) and moderate (S4, S5, S6, S7) ecological risk respectively. Only 20% of the sampling locations showed high ecological risks (S1 and S8) and as observed for EF results, Cd appeared to be the major influencing contributor to risk index. The summation of hazard quotients (HI) was greater than 1 which suggests that there is a likelihood that the people at the University maybe at risk of non-carcinogenic related diseases. However, the cancerous risks from elements were negligible as values obtained were generally lower than the acceptable limit range. This indicated that the elements concentrations in the dust samples do not pose any immediate cancer risks however the build of these elements in the environment overtime and its resultant cumulative effect is of concern, therefore, measures have to be taken to keep the elements low in the University environment.

5. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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