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HEAVY METAL CONCENTRATION, POLLUTION INDICES, SOURCE APPORTIONMENT AND HUMAN HEALTH RISK ASSESSMENT OF AIR CONDITIONER FILTER DUST IN PORT HARCOURT, SOUTH-SOUTH NIGERIA

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Abstract:
Heavy metal pollution caused by various man-made activities, which hazardously affects the environment, has become a universal concern. The aim of the study is to evaluate heavy metal concentration, pollution level and health risk assessment in air conditioner filter dust in hospitals in Port Harcourt. Dust samples were collected from air conditioner filter, and then a composite sample was made for each of the ten (10) hospitals then transported to the laboratory of FATLAB Nigeria Company. 1g of the dust was digested using Aqua regia method. Heavy metal analysis was carried using iCE 3000 Series Atomic Absorption Spectrometer. Contamination factor, I-geo value and EF were used to determine the degree of pollution, possible source was determined using Pearson correlation, principal component analysis (PCA) and cluster analysis (CA) while Health risk assessment was conducted to evaluate the non-cancer and cancer risks to children and adult in the environment. The result shows that the concentration of chromium in 52.6% (10 of 19) of the samples were higher than the Canada value (64 mg/kg), 15.8% (3 of 19) were higher than the UK value (200 mg/kg) while 5.3% (1 of 19) were higher than the Dutch value (580 mg/kg). Zinc concentration in 52.6 % (10 of 19) of the samples were higher than the Canada value (360 mg/kg) while 31.6 % (6 of 19) were higher than the Dutch value (720 mg/kg). CF value show very high contamination with Cd, I-geo indicate moderate pollution from Cd and Zn in the filter dust, EF value shows an extremely high enrichment and very high enrichment from Cd and Zn respectively. Pearson correlation shows an obviously strong relationship between Fe, Pb, Zn and Cu suggesting an emergence of heavy metal from anthropogenic source possibly resulting from office equipment, furniture, cabinetry and components of the air conditioners. More so, PCA show a strong loading with Co, Fe, Pb suggesting and emergence from anthropogenic with an element of natural sources. The primary exposure of pathway to children and adult population were ingestion. Children in the hospital environment are at risk of being exposed to the dust than the adult, basically may be due to this playing behaviour. The children and adult in the hospital environment are not at risk of developing cancer from Cd and Pb on exposure while Cr (3.24E-04, 1.39E-04) respectively, demands close attention in the environment since it is at the radar of exceeding the permissible limit. Therefore, a frequent assessment and monitoring of Air conditioner filter in the hospitals is suggested.

Key words: Air Conditioner, Filter Dust, Health Risk Assessment, Heavy Metal.

Introduction

Air conditioning system provides thermal regulation in an indoor environment such as home, offices, hospitals etc. (Ali*et al*., 2018). Approximately 80 to 90% of human population spend large amount of their time indoor and this has an essential effect on human health. Various factors affecting indoor environmental conditions mainly includes temperature, humidity, air movement, ventilation, concentration of particulate matter, biological and gaseous pollutants (Barrio-Parra *et al.,* 2018). According to Rashed (2018), air conditioner filters are the most important component of air conditioner, and studies has shown that these filters has the tendency to remove pollutants efficiently in a steady manner which therefore gets deposited on it. These deposited dusts however might be a source of contamination (Raja and Namburu, 2014). Pollutant from dust are often significantly variant in their composition, this may be as a result of natural and anthropogenic activities (Fu *et al.,* 2017). Heavy metals pollution is a major concern at global level, and they are defined by their properties such as high atomic mass, toxicity and density (Ljung *et al*., 2006). Heavy metals are higher in dust than in other environmental media and concentrations of many metals and metalloids are commonly higher in an indoor dust than an exterior settled dust in ordinary urban environments (Rasmussen, 2004; Gurzau *et al.*, 2007). More so, almost any heavy metal and metalloid may be toxic to life depending on dosage and duration of exposure (Jaishankar *et al.*, 2014). Based on a report by Hogan (2010), majority of the metals from environmental research are based on their toxicity and/or biological importance, this includes Chromium, Lead, Mercury, Cadmium, Arsenic, Copper, Manganese, Nickel, Zinc and Silver. Humans are exposed to heavy metal through various means such as ingestion of contaminated substances, skin contact, inhalation of contaminated particulates in air (Ljung *et al*., 2006). Hospital is a place with a lot of day to day activities involving both adult and children, who are exposed to dust from the hospital air conditioning system (Wang *et al.*, 2018). Over decades, global public health concern has increased with the environmental contamination due to metals. Human exposure has increased drastically as a result of an exponential increase of their utilization in various work field which includes but not limited to industrial, domestic and technological applications (Adekola and Dosumu 2011). Morgan (2013) documented that a chronic exposure to indoor dusts containing heavy metal such as lead can result in damage of the brain and nephron, learning impairment, poor muscle and bone growth, hearing damage and high blood pressure. Another research by Needleman (2004) linked neurobehavioral problems with lead exposures in children contributing to lower Intelligent Quotient, an impaired vocabulary and grammatical reasoning skills. More so, high concentration of hexavalent chromium (Cr^{6+}) which is known to be carcinogenic and toxic to humans (Jaishankar *et al.*, 2014; Olujimi *et al.,* 2015). Since air conditioning system is one of the widely used in an indoor environment which include hospital, it is crucial to determine the concentration, pollution level and human health risk of such toxic metals in dust from hospital air conditioner filter in Port Harcourt. Hence the aim of this study

Materials and Methods

Research Area

Port Harcourt is situated within the Niger Delta region at the South Western, Nigeria and it is bound by longitude 68560 to 78070 E and latitude 48440 to 48520 N of the Equator. It has a plain topography and about 5 m above sea level. This plain is well drained and provides several connections with the sea (Gulf of Guinea) by a large number of creeks and channels. Port Harcourt climate falls within the sub equatorial climate belt. Temperature and humidity are high throughout the year. The area is marked by two distinct seasons – the wet and the dry seasons with 70 percent of the annual rains falling between April and August, while 22 percent is spread in the three months of September to November. The soil type consists mainly of poorly drained silt clays mixed with sand, which is geologically classified under the Benin Formation (Ogbonna *et al.,* 2007). Port Harcourt is a major industrial city, with myriad amount of international collaboration and other industrial concerns, especially in the petroleum sector. There are refineries located in Port Harcourt, with each processing an estimated around 210,000 barrels of crude oil per day. In some areas of Port Harcourt, micro-apartment architecture is very prevalent.

Sampling and Sample Collection

Dust samples were collected from air conditioner filters by tapping the AC filters and using a plastic brush to remove the dust, then one composite sample was made for each often (10) hospitals namely; Clinic Exploit, Benette Specialist Hospital, First River Hospital, Great Tower Specialist Hospital, Kelsey Harrison Hospital, Palmo Clinic and Hospital, Palmars Hospital, Rehoboth Specialist Hospital, Sophike Medical Centre, Sterling Specialist Hospital in Port Harcourt metropolis. Samples were stored in clean labeled polyethylene sample bags and transported to the laboratory of FATLAB Nigeria Company, Ibadan for Analysis.

Sample Digestion and Heavy Metal Estimation

Dust samples were sieved with 1mm mesh size then stored for digestion. 1g of each sample was digested using 20mls *Aqua regia* solution. The samples were heated, then later cooled off, filtered and diluted with deionized water up to 50ml. The diluted samples were analyzed for heavy metals using Atomic Absorption Spectrophotometer (ICE3000AA01143203VI:30).

Degree of Pollution

The degree of pollution can be estimated using by various methods, the study however, uses Contamination factor, Geo-Accumulation Index and Enrichment factor for estimating the degree of heavy metal pollution in air conditional filter dust (Olujimi *et al.,* 2015).

Contamination factor

Contamination level of heavy metals in air conditioner filter dusts was estimated using contamination factor calculated using eqn. 1.

$$CF = {C_{\mathrm{hm\ (Sample)}}}/{C_{\mathrm{ref\ (Crust)}}} \qquad \textit{Eqn. 1}$$

Where C_{hm} sample is the concentration of heavy metals dust from the air conditioner filter and C_{ref} crust is the concentration of heavy metals in the reference level. The level of contamination is classified as follows; CF<1=Low, 1≤CF<3=moderate, 3≤CF<6=considerable, CF>6=very high.

Geo-accumulation Index

A quantitative measure of the extent of heavy metal pollution in the studied air conditioner filter dust was calculated using the geo-accumulation index. This was calculated using the equation 2 below.

$$Igeo = \text{Log}\,2\ x \left({Cn}/{1.5\ x\ Bn}\right) \qquad Eqn.\ 2$$

Where, *Cn* is the concentration of the heavy metal in the air conditioner filter dust, *Bn* is the concentration of the heavy metal in shale (background) and *1.5* is the factor compensating the background data (correction factor) due to lithogenic effects. The following interpretation are 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 and Igeo >5=extremely pollute.

Enrichment factor

Enrichment factor is used to distinguish between the anthropogenic and natural source of heavy metals in the air conditioner filter dust, to estimate the degree of the anthropogenic contribution and heavy metal contamination (Yuen *et al.*, 2012; Famuyiwa *et al.*, 2018). It was calculated using eqn 3.

$$EF = \frac{Cn\ (metal)\ /C\ (metal\ crust)}{Bn\ (reference\ metal)\ /B(reference\ crust\ )} \qquad Eqn. 3$$

Where: Cn (metal)=concentration of the measured metal, C (metal crust) =concentration of the metal in the crustal region, Bn (reference metal) = concentration of the reference metal (Fe) in the measured sample, B = concentration of reference metal (Fe) in the crustal region. A metal is regarded as a reference metal if it is of low occurrence variability and is present in trace amounts (Turekian and Wedephol, 1961). In this study, Iron (Fe) was employed as the reference metal. According to Famuyiwa *et al.* (2018) there are five categories of degree of pollution based on enrichment factor: EF<2 No or minimal enrichment, EF=2- 5 moderate enrichment, EF=5–20 significant enrichment, EF=20–40 Very high enrichment, EF>40 extremely high enrichments.

Human Health Risk Assessment

The potential health risk due to human exposure to heavy metals from indoor dust through inhalation, dermal contact and ingestion pathways was calculated according to the following equations (Zheng *et al.*, 2010). Exposure calculation for daily estimation was achieved using eqns. 4-6:

$$MDD_{ingest} = C\ x \left({IngR\ x\ EF\ x\ ED}/{BW\ x\ AT}\right)\ x\ 10^{-6} \qquad Eqn.\ 4$$

$$MDD_{inhale} = C\ x \left({InhR\ x\ EF\ x\ ED}/{PET\ x\ BWx\ AT}\right) \qquad Eqn.\ 5$$

$$MDD_{dermal} = C\ x \left({SA\ x\ DAF\ x\ SAF\ x\ EF\ x\ ED}/{BW\ x\ AT}\right) x\ 10^{-6} \qquad Eqn.6$$

Where MDD (mgkg^{-1}day^{-1}) is the mean daily dose on exposure via ingestion (MDD_{ingest}), inhalation (MDD_{inhale}) and dermal contact (MDD_{dermal}). C is the concentration of heavy metal in the air conditioner filter dust measured in mg/kg, IngR (ingestion rate) is 200mg/day for children and 100mg/day for adult and IhR (inhalation rate) is 7.63mg/day for children and 12.8mg/day for adult of heavy metal in dust respectively(USEPA 2001). ED (exposure duration) is 6 years for children and 30years for adults, and EF (exposure frequency) 350days/year for children and adult. BW and AT are the average body weight (15 kg for children and 70 kg for adult) and an average exposure time period (6 years for children and 30 years for Adults) respectively (Zheng *et al.*, 2015; Chen *et al.*, 2016). 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 (0.2mg/cm^2/d^1 for children and 0.7mg/cm^2/d^1 for adult), DAF is the dermal absorption factor used in this study is 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.

The reference dose is used as a measure of non-carcinogenic chronic hazards. Toxic effects are likely to ensue, when the exposure dose of the target contaminant exceeds the reference dose, which is generally articulated as HQ and HI. Hazard index (HI) and cancer risk method were used to assess the human health risk due to dust exposure, before calculating the HI, a hazard quotient (HQ) based on non-cancer toxic risk was calculated for individual heavy metal according to eqn. 7. (Kong *et al.*, 2011).

$$\text{HQ} = {D}/{RfD} \qquad Eqn.\ 7$$

RfD (mg/kg/day) is the daily maximum allowable dose of heavy metal without posing the non-carcinogenic risk to human during lifespan. Three different types of RfDs are used for three different exposure pathways: reference dose RfD_{ingest} (mg/kg/day) for ingestion, RfD_{dermal}, (mg/kg/day) for dermal contact and RfD_{inhale} (mg/m^3) for inhalation. The total risk of specific chemicals through multiple exposures is expressed as the hazard index (HI). The total risks of heavy metals in air conditioner filter dust through multiple exposures can be calculated using equation 8.

$$HI = \sum HQi \qquad Eqn. 8$$

Where i = different exposure pathways. The value of HI less than 1 shows that there is no significant risk of non-carcinogenic effects. However, when HI value is greater than1, there is a probability for significant non-carcinogenic effects (USEPA, 2011). The carcinogenic risks to humans are estimated using the reference dose (RfD) multiplied by respective cancer slope factor (CSF, 1mg/kg). A cancer slope factor is an upper bound probability of an individual developing cancer as a result of a lifetime exposure to dust by ingestion, inhalation and dermal contact using eqn. 9 (Olujimi *et al.*, 2015).

$$Cancer\ Risk = RfD\ x\ CSF\ Eqn.\ 9$$

Carcinogenic risk (CR) is the probability of an individual developing any type of cancer from lifetime exposure to carcinogenic hazards. CR value less than $1x10^{-6}$ specifies negligible carcinogenic risk, while CR greater than $1x10^{-4}$ recommends high carcinogenic risk to human on dust exposure (Wu *et al.*, 2015).

Data Analysis

Data were analyzed using SPSS (vs 21) to generate mean and standard deviation while Microsoft Excel 2016 was used for calculating pollution indices and graphical presentations. Source of heavy metals in the dust was estimated using Pearson Correlation, Principal Component Analysis and Cluster Analysis.

Results and Discussion

The results of CF value for heavy metals from AC filter dusts, I-geo value for heavy metals from AC filter dusts and the value for heavy metals from filter dusts (values above 10 are strictly from anthropogenic source) are presented in Figures 1 to 3 respectively. In addition to this, the results of non-cancer risks of heavy metal in AC filter dust on children and adult's exposure are presented in Figure 4. Furthermore, the results Factor Plot in Rotated Space as well as the Dendogram of the heavy metals from AC filter dust are presented in Figures 5 and 6 respectively. The Statistics of heavy metals from Hospital Air Conditioner filter dust in Port Harcourt, Nigeria and the Concetration of heavy metalsin AC filter dust from this study compared to previous indoor dust studies across the globe are presented in Tables 1 and 2 respectively. In addition, the CF, I-geo and EF values for heavy metals from AC filter dusts and the Pearson Correlation Coefficient between heavy metals are presented in Tables 3 and 4 respectively. The results of Varimax rotated principal component analysis, mean daily dose, cancer and non-cancer risk for children on dust exposure and mean daily dose, cancer and non-cancer risk for adults on dust exposure are presented in Tables 5, 6 and 7 respectively.

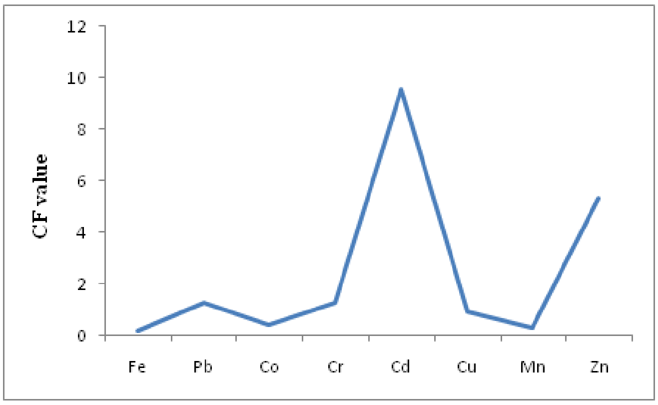


Fig. 1: CF value for heavy metals from AC filter dusts

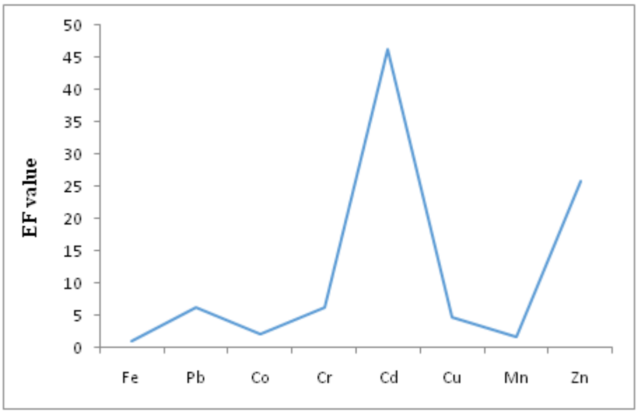


Fig. 2: I-geo value for heavy metals from AC filter dusts

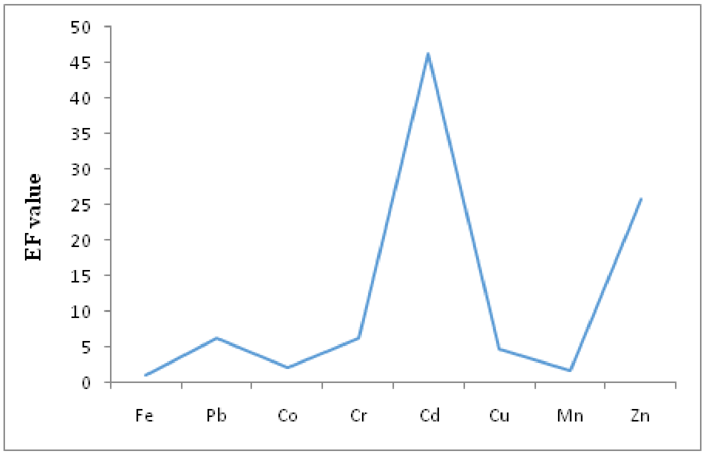
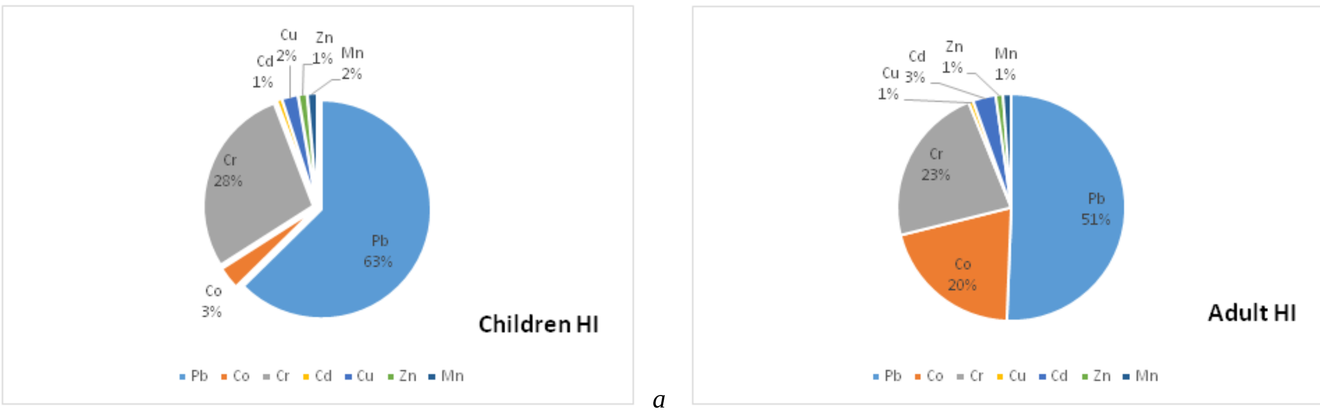


Fig. 3: EF value for heavy metals from filter dusts (values above 10 are strictly from anthropogenic source)



a *b*

Fig. 4: Non-cancer risks of heavy metal in AC filter dust on children and adult's exposure

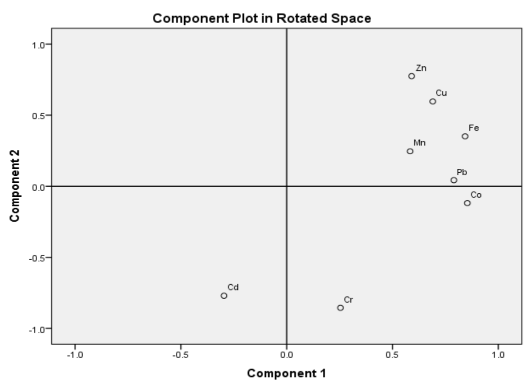


Fig. 5: Factor Plot in Rotated Space

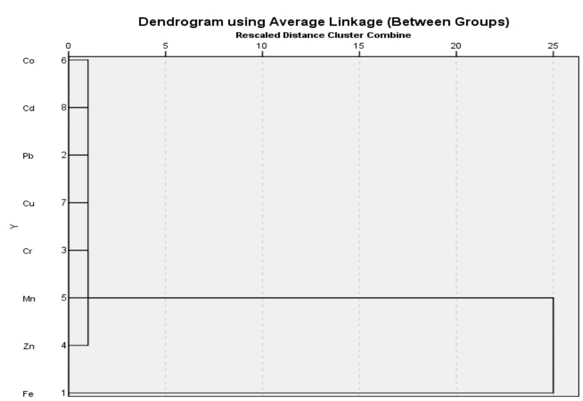


Fig. 6: Dendogram of the heavy metals from AC filter dust

Table 1: Statistics of heavy metals from Hospital Air Conditioner filter dust in Port Harcourt, Nigeria

mple ID	Heavy Metals (n=19; mg/kg)							
	Fe	Pb	Cu	Cr	Cd	Zn	Co	Mn
BMH	8830	30.0	17.4	135	6.75	153	6.58	106
BSH	9.65	-	16.0	11.0	-	338	2.7	59.2
CE	81.1	18.5	55.0	11.3	-	592	5.65	274
FRH	16300	28.4	73.9	58.0	-	1070	10.4	421
GTH	4580	29.5	11.1	118	5.43	334	7.45	459
GTS	22600	56.2	80.1	67.2	-	1025	9.40	417
KHH	20200	53.7	68.8	53.5	-	891	11.7	389
NH	9860	19.6	40.3	142	5.56	258	11.5	112
NP	5940	11.9	18.3	148	9.43	225	4.38	203
OCH	7520	33.5	41.3	298	6.85	224	15.2	112
PCH	11000	-	69.3	43.2	-	873	10.3	375
PCI	6220	20.6	16.0	515	3.25	121	8.85	456
PH	5970	22.5	33.0	26.3	-	478	7.20	210
RSH	7560	25.3	36.8	21.9	-	336	6.10	192
SMC	21000	39.6	80.1	63.7	-	910	11.5	396
SMH	6660	21.4	13.5	109	4.58	360	7.45	356
SSH	19700	31.6	78.0	54.1	-	828	10.5	370
TBC	6990	28.1	66.1	225	2.55	444	9.45	105
UPH	4400	15.6	11.7	89.1	10.3	168	3.30	149
Range	9.65-22600	0.00-56.2	11.1-80.1	11.0-515	0.00-10.2	121-1070	2.70-15.22	59.2-459
ean±SD	9760±6890	25.6±14.5	43.5±26.6	115±122	2.87±3.55	507±322	8.39±3.20	272±139
K value (2013)	-	450	-	200	150	-	-	-
CSGV (2007)	-	140	140	64	22	360	50	-
tch value inger *al.*, 2015)	-	530	190	380	12	720	-	-

Sample ID:BMH=Bratwat Memorial Specialist Hospital, BSH=Benette specialist hospital,CE=Clinic Exploit, FRH=First River Hospital,GTH=Getwell Hospital, GTS=Great Tower Specialist Hospital, KHH=Kelsey Harrison Hospital, NH=Nobsams Hospital, NP=Naphtali Physiotherapy & Wellness Clinic,OCH=Obio Cottage Hospital, PCH =Palmo Clinic and Hospital, PCI=Paragon Clinic and Imaging, PH= Palmars Hospital, RSH=Rehoboth Specialist Hospital,SMC= Sophike Medical Centre, SSH=Sterling Specialist Hospital,SMH=Save A Live Mission Hospital,TBC=The Bridge Clinic,UPH=University of Port Harcourt Teaching Hospital,CSGV= Canadian soil guideline values, DIV=Dutch intervention value.

Table 2: Concetration of heavy metalsin AC filter dust from this study compared to previous indoor dust studies across the globe

Study Locations	Fe	Pb	Cu	Cr	Cd	Zn	Co	Mn	References
Port Harcourt, Nigeria	9760	25.6	43.5	115	2.87	507	8.39	272	*This study*
Kathmandu, Nepal	-	65.3	-	158	0.89	-	-	-	Bhandari *et al.* (2021)
Sydney, Australia	-	199	272	90.0	-	1880	-	220	Israel *et al.* (2019)
Jeddah, Saudi Arabia	8750	121	-	87.9	2.09	343	8.20	391	Mansour *et al.* (2019)
Southern, Nigeria	23500	144	233	27.1	32.0	825	31.3	541	Iwegbue *et al.* (2019)
Bushehr, Iran	-	53.0	234	49.0	3.1	1420	-	-	Ardashiri and Hashem (2017)
Jenka, Malaysia	10800	1740	97.4	-	-	28.0	-	-	Sulaiman *et al.* (2017)
Abeokuta, Nigeria	13.7	27.6	59.4	41.8	855	121	4.21	328	Olujimi *et al.* (2015)
Xi'an, China	-	181	70.8	14.9	-	46280		565	Chen *et al.* (2014)
Japan	-	57.9	304		1.02	920		266	Yoshinaga *et al.* (2014)
Ottawa, Canada	-	406	206	86.7		717	8.92	267	Rasmussen *et al.* (2013)
Shah Alam city, Malaysia	4230	31.2	30.2		-	149		-	Darus *et al.* (2012)
Istanbul, Turkey	-	28.0	156	55.0	0.80	832	5.0	136	Kurt-Karakus (2012)

Table 3: CF, I-geo and EF values for heavy metals from AC filter dusts

Heavy Metals	CF value	CF scale	I_{-geo} value	I_{-geo} grade	EF value	EF Scale	Degree of Pollution
Fe	0.207	<1	-0.861	<0	1	<2	Low/Unpolluted /Minimal Enrichment
Pb	1.28	1= CF<3	-0.069	<0	6.19	5-20	Moderate/Unpolluted / Severe Enrichment
Co	0.442	<1	-0.531	<0	2.14	2-5	Low/unpolluted/ Moderate enrichment
Cr	1.28	1= CF<3	-0.070	<0	6.18	5-20	Moderate/Unpolluted/Severe Enrichment
Cd	9.57	6=	0.805	0<Igeo<1	46.3	>40	Very high/Unpolluted to moderated polluted / Extremely high enrichments
Cu	0.97	<1	-0.191	<0	4.67	5-20	Low/Unpolluted/ severe Enrichment
Mn	0.32	<1	-0.671	<0	1.55	<2	Low/Unpolluted / Minimal enrichment
Zn	5.34	3= CF<6	0.551	0<Igeo<1	25.8	20-40	Considerable/Unpolluted to moderated polluted / very high enrichment

Table 4: Pearson Correlation Coefficient between heavy metals

	Fe	Pb	Cr	Zn	Mn	Co	Cu	Cd
Fe	1							
Pb	0.723**	1						
Cr	-0.163	0.019	1					
Zn	0.764**	0.438	-0.491*	1				
Mn	0.520*	0.374	0.038	0.586**	1			
Co	0.608**	0.525*	0.288	0.403	0.289	1		
Cu	0.764**	0.485*	-0.294	0.883**	0.357	0.601**	1	
Cd	-0.391	-0.202	0.404	-0.721**	-0.383	-0.211	-0.657**	1

**. value is significant at $P<0.01$ while *. value is significant at $p<0.05$

Table 5: Varimax rotated principal component analysis

Parameter	Component 1	Component 2
Co	0.854	
Fe	0.843	0.351
Pb	0.790	
Cu	0.690	0.597
Mn	0.583	
Cr		-0.855
Zn	0.590	0.775
Cd		-0.770
Eigen value	4.26	1.60
% Variance	53.3	19.99
Cumulative	53.3	73.3

Table 6: Mean daily dose, cancer and non-cancer risk for children on dust exposure

Heavy Metals	MDD_{ingest}	MDD_{inhale}	MDD_{dermal}	HQ_{ingest}	HQ_{inhale}	HQ_{dermal}	? HQ=HI	? CR_i=TCR
Fe	6.42E-01	2.44E-08	1.80E-03					
Pb	1.68E-03	6.40E-11	4.71E-06	5.60E+00		1.35E-03	5.60E+00	1.22E-06
Co	5.52E-04	2.10E-11	1.54E-06	2.76E-02				
Cr	7.56E-03	2.87E-10	2.12E-05	2.52E+00	9.57E-06		2.52E+00	3.24E-04
Cd	1.89E-04	7.17E-12	5.28E-07	1.89E-01	7.17E-09	2.11E-02	7.17E-02	3.87E-12
Cu	2.86E-03	1.09E-10	8.01E-06	7.15E-02		2.00E-04	2.10E-01	
Mn	1.79E-02	6.80E-10	5.01E-05	1.28E-01	1.36E-08	3.58E-04	1.11E-01	
Zn	3.33E-02	1.27E-09	9.33E-05	1.11E-01		3.11E-04	1.28E-01	

Table 7: Mean daily dose, cancer and non-cancer risk for adults on dust exposure

Heavy Metals	MDD_{ingest}	MDD_{inhale}	MDD_{dermal}	HQ_{ingest}	HQ_{inhale}	HQ_{dermal}	? HQ_i=HI	? CR_i=TCR
Fe	6.88E-02	1.38E-08	1.59E-03					
Pb	1.80E-04	3.61E-11	4.17E-06	6.00E-01		1.19E-03	6.01E-01	5.25E-07
Co	5.91E-05	1.18E-11	1.37E-06	2.96E-03	2.07E-06			
Cr	8.10E-04	1.62E-10	1.87E-05	2.70E-01	5.40E-06		2.70E-01	1.39E-04
Cd	2.02E-05	4.04E-12	4.67E-07	2.02E-02	4.04E-09	1.87E-02	3.89E-02	8.76E-12
Cu	3.06E-04	6.13E-11	7.08E-06	7.65E-03		1.77E-04	7.83E-03	
Mn	1.92E-03	3.83E-10	4.43E-05	1.37E-02	7.66E-09	3.16E-04	1.40E-02	
Zn	3.57E-03	7.14E-10	8.25E-05	1.19E-02		2.75E-04	1.22E-02	

Heavy Metal Concentration in Air conditioner filter dust

The concentration of heavy metals in the hospital air conditioner filter dusts are presented in table 1; as a result of the unavailability of soil/dust guideline values in Nigeria, the UK Environmental Agency, Canada and Netherlands soil/dust guideline values were employed in the study. The concentration of Iron (Fe) ranges from 9.65-22600 mg/kg with a mean value of 9760 mg/kg. In the human body, iron is a very beneficial heavy metal. Iron is found in protein molecules such as hemoglobin and myoglobin which makes up approximately 4 gram of the adult human body. These two proteins are needed for a variety of metabolic processes in humans, as well as oxygen transport and storage in muscles (Harrison *et al.*, 2001). High concentration of iron higher than 10000 was recorded for 31.6 % of the samples with the highest concentration recorded in the AC filter dust following this pattern; Great Tower Specialist Hospital (22600mg/kg)>Sophike Medical Centre (21000 mg/kg)>Kelsey Harrison Hospital (20200 mg/kg)> Sterling Specialist Hospital (19700 mg/kg). Mean value of Iron from the study was higher than the concentration reported in various indoor dust such as Jeddah, Saudi Arabia (8,750 mg/kg), Mansour*et al.* (2019), Abeokuta (13.7 mg/kg), Olujimi *et al.* (2015) and Shah Alam city, Malaysia (4230 mg/kg), Darusa*et al.* (2012) but lower than that of Southern-Nigeria (23,499 mg/kg), Iwegbue*et al.* (2019) and Jenka, Malaysia (10800 mg/kg), Sulaiman *et al.* (2017); see table 2.

The concentration of Lead from the study ranges from 0.00-56.2mg/kg with a mean value of 25.6 mg/kg. Lead concentration was recorded to be high in 10.5% (2 of 19) of the samples with the highest concentration recorded in the AC filter dust from Great Tower Specialist Hospital (56.2 mg/kg). Lead poisoning is a toxicity caused by excessive lead consumption and this disease affects both children and adults' gastrointestinal tracts and central nervous systems (Kung *et al.*, 2012). Lead concentrations from the study were extensively lower than the soil guideline value stated by the CLEA, UK (450 mg/kg), Canada (140 mg/kg) and Dutch guideline value (530 mg/kg) for lead in dust; see table 1. In comparison to other dust studies, mean value similarity occurs with studies by Olujimi *et al.* (2015) in Abeokuta, Nigeria (27.6 mg/kg), Kurt-Karakus (2012) in Istanbul, Turkey (28.0 mg/kg) and Darus *et al.* (2012) in Shah Alam city, Malaysia (31.2 mg/kg). The concentration is also two or more times lower than various dust studies by Bhandari *et al.* (2021) in

Kathmandu, Nepal (65.3 mg/kg), Sulaiman*et al.* (2017)in Jenka, Malaysia (121 mg/kg), Rasmussen *et al.* (2013) in Ottawa, Canada (406 mg/kg) and from house vacuum dust by Israel *et al.* (2019) in Sydney, Australia (199 mg/kg) (see table 2).

The concentrations of Copper from the study ranges from 11.1 to 80.1 mg/kg with a mean value of 43.5 mg/kg. High Copper concentration was recorded in 42.1% (8 of 19) of the samples with the highest value recorded equally in both Great Tower Specialist Hospital and Sophike Medical Centre. The sources of copper are from cables, air conditioner components and various copper coated equipment. Excessive exposure to copper could result in cellular damage resulting in DNA damage (Mutation) and proteins and lipids oxidation (Iwegbue*et al.*, 2019). Copper concentration was lower than the soil guideline value for copper by Canada (140 mg/kg) and Dutch guideline value (190 mg/kg) in dust (table. 1). Copper concentration in the study was higher than the values recorded from a study by Darus *et al.* (2012) in Shah Alam city, Malaysia (30.2 mg/kg) but lower than various dust studies recorded in Abeokuta, Nigeria (59.4 mg/kg) by Olujimi*et al.* (2015), Jenka, Malaysia (97.4 mg/kg) by Sulaiman *et al.* (2017), Bushehr, Iran (234 mg/kg) by Ardashiri and Hashem (2017), Southern, Nigeria (233 mg/kg) by Iwegbue *et al.* (2019) and Ottawa, Canada (206 mg/kg) by Rasmussen *et al.* (2013) (see table 2).

Chromium concentration from the study ranges from 11.0-515 mg/kg with a mean value of 115 mg/kg. Chromium concentration in 52.6% (10 of 19) of the samples were higher than the Canada soil guideline value (64 mg/kg), 15.8% (3of 19) of the samples were higher than the UK value (200 mg/kg) while 5.3% (1 of 19) of the samples were higher than the Dutch value (580 mg/kg). High chromium concentration in the hospital filter dust take the following order; Paragon Clinic and Imaging>Obio Cottage Hospital> The Bridge Clinic> Naphtali Physiotherapy & Wellness Clinic> Nobsams Hospital> Bratwat Memorial Specialist Hospital> Getwell Hospital> Save A Live Mission Hospital> University of Port Harcourt Teaching Hospital> Sophike Medical Centre; see table 1. The sources of chromium are wall paints from the room and the components of Air conditioners (Mohanty *et al.*, 2013). Chromium exist as trivalent $Cr^{3+}$and Hexavalent mets, with the hexavalent Cr^{6+} being the most toxic. A prolonged exposure to chromium in the hospital can result in health problems such as cardiac, renal, hepatic, blood and brain effects of the patients (Gupta *et al.*, 2013). Mean Chromium concentration were higher than the values recorded from various dust studies by Olujimi *et al.* (2015) in Abeokuta, Nigeria (41.8 mg/kg), Ardashiri and Hashem (2017) in Bushehr, Iran (49.0 mg/kg), Kurt-Karakus (2012) in Istanbul, Turkey (55.0 mg/kg),Rasmussen *et al.* (2013) in Ottawa, Canada (86.7 mg/kg) and Iwegbue *et al.* (2019) in Southern, Nigeria (27.1 mg/kg) but lower than a study by Bhandari *et al*. (2021) in Kathmandu, Nepal.

Cadmium concentration from the study ranges from 0.00-10.2 mg/kg with a mean of 2.87±3.55 mg/kg. Cadmium was not detected in 52.6 % (10 of 19) of the samples. The highest concentration was recorded in University of Port Harcourt Teaching Hospital (10.3 mg/kg).The primary sources of cadmium are infiltration of automobile exhaust contaminated particles. Prolonged exposure to excessive cadmium can seriously affect the lungs, DNA and testicular damage or cancer development (Faridi *et al.,* 2014). The mean cadmium concentration was lower than the soil guideline value stated by the CLEA, UK (150 mg/kg), Canada value (22 mg/kg) and Dutch intervention value (12 mg/kg) in soil/dust; see table 1. Mean Cadmium concentration from the study was similar to that of cadmium concentration recorded from some studies in Jeddah, Saudi Arabia (2.09 mg/kg) by Mansour*et al.* (2019), Bushehr, Iran (3.1 mg/kg) by Ardashiri and Hashem (2017), Istanbul, Turkey (0.84 mg/kg) by Kurt-Karakus (2012) and USA (4.3 mg/kg) by Zota *et al.* (2011) but lower than the cadmium value recorded in Ottawa, Canada (6.46 mg/kg) by Rasmussen *et al.* (2013), Southern-Nigeria (32.0 mg/kg) by Iwegbue *et al.* (2019) and Abeokuta, Nigeria (855 mg/kg) by Olujimi *et al.* (2015); see table 2.

Zinc concentration ranges from 121-1070mg/kg with a mean value of 507 mg/kg. Zinc concentrations in 52.6 % (10 of 19) of the samples were higher than the Canada value (360 mg/kg) while 31.6 % (6 of 19) of the samples were higher than the Dutch value (720 mg/kg). Zinc concentration in the filter dust follows an increasing order of First River Hospital>Great Tower Specialist Hospita> Sophike Medical Centre> Kelsey Harrison Hospital> Palmo Clinic and Hospital> Sterling Specialist Hospital> Clinic Exploit> Palmars Hospital> The Bridge Clinic> Save A Live Mission Hospital; see table 1. Zinc is mostly found in the crustal region including a number of ores, it is also used to galvanize other metals to avoid rusting. Paint pigments, pesticides, batteries and electrical appliances are all made from zinc (Tripathi, 2017).The sources of zinc in majority of the samples are wall paints, air conditioner components and roofing sheets. Prolonged exposures to zinc in the above samples can result in both acute and chronic effects; acute ingestion may cause abdominal pain, nausea, vomiting, diarrhea, headache, lethargy and possibly bleeding. More so, may cause muscle weakness, shortness of breath, copper deficiency, suppressed immunity, reduced High Density Lipoprotein which can stimulate heart attack (Tripathi, 2017). Zinc concentration from the study were lower than the report from various dust studies such as Ottawa, Canada (717 mg/kg) by Rasmussen *et al.*(2013), Istanbul, Turkey (832 mg/kg) by Kurt-Karakus (2012), Southern-Nigeria (825 mg/kg) by Iwegbue *et al.*(2019), Jenka, Malaysia (2879 mg/kg) by Sulaiman *et al.*(2017), Sydney, Australia (1876 mg/kg) by Israel *et al.* (2019) and Bushehr, Iran (1423 mg/kg) by Ardashiri and Hashem (2017) (see table 2).

Cobalt concentration from the study ranges from 2.70-15.22 mg/kg with a mean value of 8.39 mg/kg. The highest concentration was recorded in Obio Cottage Hospital, Althogh all samples were within the Canada soil guideline value (50 mg/kg); see table 1. Cobalt sources in the filter dust may be dust particulate from outdoor pollution and air conditioner casing (Iwegbue*et al.*, 2019). A prolong exposure to cobalt result in asthma, pneumonia, eye effect, cardiac problems, and thyroid damage (Al-Fartusie and Mohssan, 2017).Mean cobalt concentration from the study was similar to the various dust studies in Jeddah, Saudi Arabia (8.2 mg/kg) by Mansour *et al.*(2019), Ottawa, Canada (8.92 mg/kg) by Rasmussen *et al.*(2013) but slightly higher than those recorded in Abeokuta, Nigeria (4.21

mg/kg) by Olujimi *et al.* (2015) and Istanbul, Turkey (5.0 mg/kg) by Kurt-Karakus (2012) while it was lower than that of Southern, Nigeria (31.3 mg/kg) by Iwegbue *et al.* (2019) (see table 2). Manganese is an essential element in the human body however, the deficiency can lead to blood clotting, skeletal abnormalities, changes in hair color, fatness, glucose sensitivity, and reduced cholesterol levels (Spangler and Reid, 2010). Manganese concentration in the study ranges from 59.2-459 mg/kg with a mean value of 272 mg/kg. Manganese concentration higher than 200 mg/kg was recorded in 63.2 % (12 of 19) of the samples with the highest in Getwell Hospital (459 mg/kg); see table 1. A prolonged exposure to manganese causes damage to the respiratory tract and brain, headaches, sluggish joints, insomnia, forgetfulness, and nerve damage. Lung embolism, bronchitis and impotency in men (Hock *et al.*, 2013). Manganese concentration from the study was higher than reports from various dust such as Sydney, Australia (220 mg/kg) by Israel *et al.* (2019), Ottawa, Canada (267 mg/kg) by Rasmussen *et al.* (2013), Japan (266) by Yoshinaga *et al.* (2014) and Istanbul, Turkey (136 mg/kg) by Kurt-Karakus (2012) but lower than reports made from Jeddah, Saudi Arabia (391 mg/kg) by Mansour*et al.* (2019), Abeokuta, Nigeria (328 mg/kg) by Olujimi *et al.* (2015) and Xi'an, China (565 mg/kg) by Chen *et al.* (2014), Southern-Nigeria (825 mg/kg) by Iwegbue *et al.* (2019); see table 2.

Degree of Pollution

Contamination Factor

Contamination factor value are shown in table 3 and fig. 1., Fe, Co, Cu and Mn are of low contamination, Pb and Cr are of moderate contamination, Zn and Cd were of considerable and very high contamination respectively in the filter dust. Cd appear the principal contaminant of the dust. The CF value for the heavy metals are in a downward trend of Cd>Zn>Pb>Cr>Cu>Co>Mn>Fe.

Geo-Accumulation Index

Pollution assessments through geo-accumulation index of heavy metals in the air conditioner filter dust are shown in table 3 and fig. 2. The air conditioner filter dusts are unpolluted for majority of the heavy metals; Fe, Pb, Co, Cr, Mn and Cu while they are also unpolluted to moderate polluted for Cd and Zn. The I_{geo} value of heavy metal occurs in the decreasing order of Cd>Zn>Pb>Cr>Cu>Co>Mn>Fe. The filter dusts were not polluted for all the heavy metals since their values were less than 1.

Enrichment Factor

The enrichment factor value estimated for heavy metals in AC filer dust from Hospitals are shown in table 3 and fig. 3, reveals that Fe and Mn are of minimal enrichment, Co (2.14) a moderate enrichment, Pb, Cr and Cu were of severe enrichment, Zn (25.8) a very high enrichment while Cd (46. 3) an extremely very high enrichment in the filter dust. The enrichment of heavy metal is in the trend of Cd>Zn> Pb>Cr> Cu>Co>Mn>Fe. EF shows an identical pattern with the contamination factor, the EF value for Cd and Zn were above 10, suggesting a strict anthropogenic source, other heavy metals were lower than 10 and also greater or equal to 1. This suggest a partial emergence from mixed anthropogenic and natural sources.

Source Apportionment

Pearson's correlation matrix

The relationship between heavy metals in table 4., is an indicator for suggesting the source in the examined environment (Rodríguez *et al*., 2008). Pearson correlation from the study shows that Fe is positively associated to Pb (0.723), Zn (0.764), Co (0.608), Cu (0.764) at $P<0.01$. and Mn (0.520) at $P<0.05$. Pb is associated to Co (0.525) and Cu (0.485) at $p<0.05$. Cr is negatively associated to Zn (-0.491) at $p<0.05$. Zn is positively associated to Mn (0.586), Cu (0.883) and negatively associated to Cd (-0.721) at $p<0.05$. Co is positively associated to Cu (0.601) while Cu is negatively associated to Cd (-0.657). The obviously strong positive relationship between Fe,Pb,Zn and Cu suggests that the heavy metals are principally from anthropogenic source, more so, the negative association from heavy metals to Cd, suggest that Cd is purely from lithogenic source.

Principal Component Analysis

The principal component analysis of air conditioner filter dust considers only the Eigen values exceeded 1 are shown in table 5, the factors were plotted in rotated space to show the relationship between the heavy metals and possibly suggesting the common sources, fig. 5. Two components were extracted making up 73.29 % of the overall variance. First component accounted for 53.3 % of the total variance and a strong loading with Co, Fe and Pb this suggest an anthropogenic source with an element of a natural source. The anthropogenic sources could be from infiltrating of outdoor dust polluted with vehicular and generator emissions. The second component accounted for 19.99 % of the overall variance and a strong loading with Zn the sources of which are anthropogenic elements associated to fuel and lubricants in vehicles and generator set, furniture and cabinetries preservatives (Iwegbue*et al.*, 2013; 2017). More so, the negative loading observed with Cr and Cd indicates a pure natural source.

Human Health Risk Assessment

Non-carcinogenic and Carcinogenic Risk

The level of children and adults' exposure to heavy metal in the air conditioner filter dust via ingestion, inhalation and dermal contact can be estimated using the mean daily dose (Bhandari *et al*. 2021). The mean daily doses of heavy metals in the filter dust on exposure are shown in tables 6 and 7. The values are higher in ingestion and dermal contact for both children and adult. This occur in the order of ingestion>dermal>inhalation. Children in the hospital environment are exposed to heavy metals in dust than the adult; this is justifiable since children are known for their crawling and hand–mouth behavior when playing. The health assessment of children and adults in the environment, estimated based on non-carcinogenic and carcinogenic risks of via different exposure media are shown in tables 5 and 6. The non-carcinogenic risk value are said to be significant if the hazard index value is greater than 1 (Wu *et al*. 2015). Hazard index (HI) value from the study shows that all heavy metals were less than 1, suggesting non- significant, non- carcinogenic risk. Although, Cr (2.52 E+00) and Pb (5.60E+00) in children population are approaching the permissible limit and this calls for attention. Total carcinogenic risk (TCR) of the children and adult in the hospital environment are evaluated using a permissible range ($1x10^{-6}$ to $1x10^{-4}$). The population will be marked as being at carcinogenic risk if it is greater than $1x\ 10^{-4}$ (Wu *et al*. 2015; Yadav *et al.,* 2017). The total carcinogenic risk value from the study shows that the children and adult in the hospital environment are not at risk of developing cancer from Cd and Pb on exposure while Cr (3.24E-04, 1.39E-04) respectively, demands close attention in the environment since it is at the ream of exceeding the permissible limit.

Conclusion

Dust samples collected from air conditioner filter in ten (10) hospitals in Port Harcourt, Nigeria shows high concentration of Cr and Zn in large proportion of the samples exceeding the stated values for the element in soil by the Canada, UK and Dutch intervention value. Pollution indices show Cd and Zn to be the major pollutant in the filter dust. The possible sources of Fe, Pb, Zn, Cu, Co are majorly anthropogenic with very few natural sources. Ingestion serves as the major exposure pathway in the hospital environment, both children and adult in the hospital environment are not at risk of developing cancer from Cd and Pb on exposure but Cr demands close attention in the environment. Therefore, a frequent assessment and monitoring of Air conditioner filter in the hospitals is recommended.

References

Adekola F. A. and Dosumu O. O. (2011) Heavy metal determination in household dust from Ilorin City, Nigeria. *J Niger Soc Exp Biol*.;*3*(1):217–21.

Al-Fartusie, F. S. and Mohssan, S. N. (2017). Essential Trace Elements and Their Vital Roles in Human Body, *Indian Journal of Advances in Chemical Science, 5(*3), 127-136

Ali, M. U., Liu, G., Yousaf, B., Abbas, Q., Ullah, H., Munir, M. A. M. and Zhang, H. (2018). Compositional characteristics of black-carbon and nanoparticles in air-conditioner dust from an inhabitable industrial metropolis. *Journal of Cleaner Production, 180, 34–42.* doi:10.1016/j.jclepro.2018.01.161

Ardashiri, S. and Hashem, S. E. (2017). Health risk assessment of heavy metals in indoor dust from Bushehr, Iran. *Iran. J. Health Saf. Environ.5*, 966–971.

Barrio-Parra, F., De Miguel, E., Lazaro-Navas, S., Gomez, A. and Izquierdo, M. (2018). Indoor dust metal loadings: a human health risk assessment. *Expo. Health* 10 (1), 41-50

Bhandari, S., Sudarshana, S., Bijaya, A., Mahesh, S., Bindra, D. S., Achut, R. P., Prem, K. S., Ramesh, Kaji, S., Dipesh, R. P. and Pawan, R. S. (2021). Non-carcinogenic and Carcinogenic Risk Assessment of Heavy Metals Exposure to Indoor Dust in Kathmandu, Nepal. *Journal of Nepal Chemical Society, 42*(1), 16-28 DOI: https://doi.org/10.3126/jncs.v42i1.35324

Chen, H., Lu, X. and Li, L. Y. (2014). Spatial distribution and risk assessment of metals in dust based on samples from nursery and primary schools of Xi'an, China. *Atmospheric Environment*, 88, 172–182. doi: 10.1016/j.atmosenv.2014.01.054

Darus, F. M., Nasir, R. A., Sumari, S. M., Ismail, Z. S, Omar, N. A. (2012). Heavy metals composition of indoor dust in nursery schools building. *Procedia Soc Behav Sci*. 38:169–75.

Famuyiwa**,** O. A., Lanre-Iyanda, Y. A. and Osifeso, O.**(2018)** Impact of Land Use on Concentrations of Potentially Toxic Elements in Urban Soils of Lagos, Nigeria, *Journal of Health & Pollution*. 8,(19), *180904*

Faridi, S., Hassanvand, M. S., Naddafi, K., Yunesian, M., Nabizadeh, R., Sowlat, M. H., … Alimohammadi, M. (2014). Indoor/outdoor relationships of bioaerosol concentrations in a retirement home and a school dormitory. *Environmental Science and Pollution Research, 22(11), 8190–8200.* doi:10.1007/s11356-014-3944-y

Fu, Q., Lyu, D., Zhang, L., Qin, Z., Tang, Q., Yin, H. and Yao, K. (2017). Airborne particulate matter (PM2.5) triggers autophagy in human corneal epithelial cell line. *Environmental Pollution,* 227, 314–322. doi: 10.1016/j.envpol.2017.04.078

Gupta, N., Gaurav, S. S. and Kumar, A. (2013). Molecular Basis of Aluminium Toxicity in Plants: A Review. *Am J of Plant Sci.*; 4:21–37

Gurzau, E., Gurzau, A., Neamtiu, I. and Coman, A. (2007). Integration of metal bioavailability in risk assessment policy decision making. *Environ Earth Sci. 2*(1) pp. 349-368.

Israel, N.Y. D., Cynthia, F. I., Neda, S. S., Mark, P. T. (2019). Human exposure and risk associated with trace element concentrations in indoor dust from Australian homes. *Environment International. 133, 105125*

Jaishankar, M., Tseten, T., Anbalagan, N., Mathew, B. B., and Beeregowda, K. N. (2014). Toxicity, mechanism and health effects of some heavy metals. *Interdisciplinary Toxicology, 7(2), 60–72.* doi:10.2478/intox-2014-0009

Yoshinaga, J., Yamasaki, K., Yonemura, A., Ishibashi, Y., Kaido, T., Mizuno, K., Takagi, M., Tanaka, A., (2014). Lead and other elements in house dust of Japanese residences – sources of lead and health risks due to metal exposure. *Environ. Pollut.* 189, 223–228. https://doi.org/10.1016/j.envpol.2014.03.003.

Kurt-Karakus, P. B., (2012). Determination of heavy metals in indoor dust from Istanbul,Turkey: estimation of the health risk. *Environment International*. 50, 47–55. https://doi.org/10.1016/j.envint.2012.09.011

Iwegbue, C. M. A., Grace, O., Onoriode, O. E., Eze, W. O., Francis, E. E., Godswill, O. T., Godwin. E. N. and Bice, S. M. (2018). Characterization of metals in indoor dusts from electronic workshops, cybercafés and offices in southern Nigeria: Implications for on-site human exposure. *Ecotoxicology and Environmental Safety* 159, 342–353

Iwegbue, C. M. A., Nnamdi, N., Francis, E. E., Eze, W. O., Godswill, O. T., Godwin, E. N. and Bice, S. M. (2019) Risk assessment of human exposure to potentially toxic metals in indoor dust from some small and medium scale enterprise workplace environments in southern Nigeria, *Indoor and Built Environment* 1–18 DOI: 10.1177/1420326X19876007

Iwegbue, C. M. A., Oliseyenum, E. C. and Martincigh, B. S. (2017). Spatio-temporal distribution of metals in household dust from rural, semi-urban and urban environments in the Niger Delta, *Nigeria. Environ Sci Pollut Res*. 24: 14040–14059

Iwegbue, C. M. A., Ossai, E. K., Overah, C. L., Opuene, K., Nwajei, G. E. (2013). Distribution of metals in urban street dusts of Benin City, Nigeria. *Pak. J. Sci. Ind. Res. Ser. A: Phys. Sci*. *56*(3), 165 –175.

Ljung, K., Schinus, O. and Otabbong, E. (2006). "Metal in soil of children's Urban environment in the small northern European city of Uppsala," *Science of the Total Environment*, vol. 366 no. 2-3 pp. 749 – 759,

Mansour A. A., Salwa K. H., Noura, A. A., Fahd, M. A. and Mamdouh, I. K. (2019) Risk Assessment and Implications of School Children Exposure to Classroom Heavy Metals Particles in Jeddah, Saudi Arabia. *Int. J. Environ. Res. Public Health*2019, 16, 5017; doi: 10.3390/ijerph16245017

Morgan, R. (2013). Soil, heavy metals, and human health. In. Brevik EC, Burgess LC (eds). *Soils and human health*. CRC Press: Boca Raton, FL; 59–82.

Mohanty, M. and Kumar, P. H. (2013). Effect of ionic and chelate assisted hexavalent chromium on mung bean seedlings (Vigna Radiata l. Wilczek. Var k-851) during seedling growth. *JSPB. 9*(2):232–241.

Needleman, H. (2004). Lead poisoning. *Annual Review of Medicine*,*55*(1), 209-211

Ogbonna, D. N., Amangabara, G. T., and Ekere, T. O. (2007). Urban solid waste generation in Port Harcourt metropolis and its implications for waste management. Management of Environmental Quality*: An International Journal, 18*(1), 71–88. Doi: 10.1108/14777830710717730

Olujimi, O., Oliver, S. and Walter, G. (2015) Pollution indexing and health risk assessments of trace elements in indoor dusts from classrooms, living rooms and offices in Ogun State, Nigeria.*Journal of African Earth Sciences* 101, 396–404

Raja, R. T. and Namburu, S. (2014**)** Impact of Heavy Metals on Environmental Pollution,*Journal of Chemical and Pharmaceutical Sciences.* vol. 55, pp. 209-214.

Rashed M. N. (2018). Total and extractable heavy metals in indoor, outdoor and street dust from Aswan City, Egypt. *Clean (Weinh)*; *36*(10- 11):850–857

Rasmussen, P. E. (2004). Can metal concentrations in indoor dust be predicted from soil geochemistry?*Canadian Journal of Analytical Sciences and Spectroscopy*, 49, 166-174.

Rasmussen, P. E., Levesque, C., Chenier, M., Gardner, H. D., Jones-Otazo, H., Petrovic, S., (2013). Canadian house dust study: population based concentrations, loads and loading rates of arsenic, cadmium, chromium, copper, nickel, lead, and zinc inside urban homes. *Sci. Total Environ.* 443, 520–529. https://doi.org/10.1016/j.scitotenv.2012. 11.003.

Spangler, J. G. and Reid, J. C. (2010). Environmental Manganese and Cancer Mortality Rates by County in North Carolina: An Ecological Study. *Biological Trace Element Research*, 133(2), 128–135. doi:10.1007/s12011-009-8415-9

Sulaiman, F. R., Bakri, N. I. F., Nazmi, N. and Latif, M. T. (2017). Assessment of heavy metals in indoor dust of a university in a tropical environment. *Environ. Forensics*. *18*, 74–82.

Tripathi, N., Choppala, G., & Singh, R. S. (2017). Evaluation of modified chitosan for remediation of zinc contaminated soils. Journal of Geochemical Exploration, 182, 180–184. doi:10.1016/j.gexplo.2016.08.011

Wang, F., Zhou, Y., Meng, D., Han, M. and Jia, C. (2018). Heavy metal characteristics and health risk assessment of PM 2.5 in three residential homes during winter in Nanjing, China. *Building and Environment*, *143,* 339–348. doi: 10.1016/j.buildenv.2018.07.011

Wu, S., Peng, S., Zhang, X., Wu, D., Luo, W. and Zhang, T. (2015) Levels and health risk assessments of heavy metals in urban soils in Dongguan, *China. J. Geochem*. Explor. 148, 71-78.

Yadav, I. C., Devi, N. L., Li, J. and Zhang, G. (2017). Polycyclic aromatic hydrocarbons in house dust and surface soil in major urban regions of Nepal: implication on source apportionment and toxicological effect. *Sci. Total Environ.* Vol. 616–617, Pp. 223-235 https://doi.org/10.1016/j.scitotenv.2017.10.313

Yuen, J. Q., Olin, P. H., Lim, H. S., Benner, S. G., Sutherland, R. A. and Ziegler, A. D. (2012). Accumulation of potentially toxic elements in road deposited sediments in residential and light industrial neighborhoods of Singapore. *J. Environ. Manag.*, 101, 151–163.