Bio-Accessibility and Health Risk Assessment of Heavy Metals in Indoor Dust From Higher Institutions in Ondo State, Nigeria

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**BIO-ACCESSIBILITY AND HEALTH RISK ASSESSMENT OF HEAVY METALS IN
INDOOR DUST FROM HIGHER INSTITUTIONS IN ONDO STATE, NIGERIA**

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Abstract

Quality of indoor air has been a major concern over time particularly in urban areas. Amidst the indoor air parameters, particulate matter/dust is of core interest owing to the fact that it acts as sediment for metals and other pollutants. Considering the ample amount of time spent indoor by students, this study has been mapped out to investigate the quality of air in tertiary institutions in Ondo State, Nigeria based on their proximity to more anthropogenic activities. Herein, pH, conductivity, and anion concentrations in the indoor dust samples were estimated employing standard analytical methods. Our findings revealed a sequence of anion concentration level as follows, $\text{Cl}^- > \text{SO}_4^{2-} > \text{NO}_3^-$. Also, the concentrations of some selected metals were analyzed using flame atomic absorption spectrophotometer (FAAS). The variation in metal concentration observed in most study sites was in the order $\text{Cu} > \text{Zn} > \text{Cr} > \text{Pb} > \text{Cd}$. The mean heavy metal variation followed the trend based on the sample collection sites considered in the present study with $\text{FE} > \text{OA} > \text{FU} > \text{HT}$ and Cu (0.480mg/kg), Zn (0.409mg/kg), Cr (0.407mg/kg), Pb (0.149mg/kg) and Cd (0.029mg/kg) being the highest concentration of each of the metals. However, all the metal concentrations were below the permissible level. The result from non-carcinogenic study indicates that the average daily dose (by ingestion) was found to be the core exposure pathway such that $\text{ADD}_{\text{ing}} > \text{ADD}_{\text{derm}} > \text{ADD}_{\text{inh}}$. Nevertheless, the hazard quotient (HQ) and hazard index (HI) were less than 1. This implies that no potential health risk. More generally, a relative degree of safety and strict regulations is suggested to be put in place to maintain the status.

Keywords: Indoor Dust, Heavy Metals, Health Risk, Exposure Pathway, Tertiary Institution, Ondo State

Abbreviation

FU: Federal University of Technology Akure (FUTA); **FE:** Federal College of Agriculture (FECA); **HT:** Ondo State College of Health Science Technology (OSCOHST), Akure; **OA:** Adeyemi College of Education (ACE); **ADD_{ing}:** average daily dose via ingestion; **ADD_{inh}:** average daily dose via inhalation; **ADD_{derm}:** average daily dose via dermal contact

Introduction

Air quality is a major concern with respect to the fast growing population and unprecedented rise in urbanization, technological advancement and industrial activities (Wu et al. 2015; Zhang et al. 2015). The physiochemical compositions of air are altered by organic compounds such as poly-aromatic hydrocarbons (PAHs) (Wang et al. 2010), airborne particulate matter (Saeedi et al. 2012; Keshavarzi et al. 2015), inorganic compounds such as heavy metals among others (Li et al. 2017).

Indoor dust is a heterogeneous mixture of inorganic and organic particles that varies in size and shape and may penetrate easily into lungs and bloodstreams (Zheng et al. 2017). Generally, the concentration of heavy metals in background soil of any area is usually lower than that in airborne dust as a result of several factors which may include surface area of the later, agglomeration of dust particles, atmospheric turbulence, etc (Mohmand et al. 2015; Li et al. 2017). The presence of indoor dust is a serious issue with sit-at-home parents and sedentary individuals in the office while presence of heavy metals in such could increase the possible environmental issues that are associated with them (Darus et al. 2012). This may include increase in atmospheric solar radiation, concentration of total suspended solids and change in size of cloud condensation nuclei among others (Darus et al. 2012; Keshavarzi et al. 2015).

The infiltration of outdoor pollutants resulting from rock blasting, industrial discharge (Thorton 1991), vehicle emissions (Khoder et al. 2010), coal pulverization (Charlesworth et al. 2011), attached particles to footwear's are external sources of heavy metals in indoor dust due to outdoor ↔ indoor equilibrium (Turner 2011). In contrast, paint composition such as pigment (PbO_2 , TiO_2 , etc.) (Chattopadhyay et al. 2003), carpet backing (Fergusson and Kim 1991), indoor heating and combustion of fossil fuel (Turner, 2011), electrical appliances (Lau et al. 2014), etc. are internal sources of heavy metals in indoor dust. Exposure to indoor dust with a high concentration of heavy metals via ingestion, inhalation, and dermal contact can lead to inhibition of biochemical and neurological activities (Duruibe et al. 2007; Rout et al. 2015). The metals could undergo rapid chemical reactions owing to their reactivity and variable oxidation state. This may result in mutagenesis, genotoxicity, non-carcinogenic and carcinogenic health risk (Kang et al. 2011). This study is therefore designed to monitor the air quality of post-secondary institutions in Ondo state, Nigeria by evaluating the concentration of selected heavy

metals in airborne particulate matter and thus estimating the potential human health risk associated with oral, respiratory and dermal contact from the selected heavy metals.

Materials and methods

Sample collection

Indoor dust samples used for this study were obtained during dry season (December – Mid March) from four higher institutions of learning in Ondo State, Nigeria. They include Federal University of Technology Akure (FUTA)-a university, Federal College of Agriculture (FECA)-a monotechnic, Ondo State College of Health Science Technology (OSCOHST)-a health college, Akure and Adeyemi College of Education (ACE). Selection of these higher institutions within the state was based on their proximity to more anthropogenic actions such as industrialization, urban construction, and automobile movement among other parameters. A total of 20 g air particulate matter samples were collected from each of the study sites by gently dusting surfaces of doors, windows, and bookshelves in different lecture rooms, hostels, laboratories and libraries with polyethylene brush, stored in polypropylene bottles until analysis. Samples obtained from FUTA were labeled as FU, those from FECA as FE, those from OSCOHST as HT and those from ACE as OA.

pH determination

The pH of the samples was determined by the method of Rowell et al. (1994). Briefly, 2 g of (each) sample was weighed into a beaker and 50 mL of distilled water was added. The mixture was left for 30 min and stirred at regular intervals. Upon completion, the electrode of a pre-calibrated Hanna pH meter (model HI2210 obtained from Italy) was dipped into the solution and the pH value was read and recorded.

Conductivity determination

The method of Rowell et al. (1994) was employed for conductivity determination. Typically, 2 g of (each) sample was weighed into a beaker and 50 mL of distilled water was added. The mixture was left for 30 min and stirred at regular intervals. Then, the conductivity was read with a conductivity meter (Jenway4520, UK), which was pre-calibrated using 1M KCl at 25°C.

Analysis of anionic concentration of dust sample

2 g of (each) sample was dissolved in 100 mL of distilled water in a 250 mL Erlenmeyer flask and placed in a mechanical shaker for 24h for equilibration to prepare a stock sample. Thereafter, the solution was filtered and subsequently used for the determination of chloride, sulfate, and nitrate.

Chloride content determination

The chloride content of (each) sample was determined by Mohr's method (Meija et al. 2016). Typically, 2 mL of stock sample was taken and 0.02g of NaHCO₃ was added until effervescence ceased. Upon completion, 2 mL of K₂Cr₂O₄ was introduced and stirred to enhance equilibration. The solution was titrated to the first permanent appearance of red Ag₂Cr₂O₄. The percentage of chloride is calculated using the formula below.

$$\text{Mole of } Cl^{-} = V_{AgNO_3} \times M_{AgNO_3} \quad (1)$$

$$\text{Where, Mass of } Cl^{-} = \text{Mole of } Cl^{-} \times \text{Molar mass} \quad (2)$$

$$\%Cl^{-} = \frac{\text{Mass of } Cl^{-}}{\text{Sample mass}} \times 100 \quad (3)$$

Sulphate content determination

The method of Samira et al. (2009) was adopted for the determination. Briefly, 5 mL (each) of stock sample was diluted up to 100 mL using distilled water and thereafter transferred into a 250 mL conical flask. 5 mL conditional reagents (a mixture of 50 mL glycerol, 30mL conc. HCl, 300mL distilled water, 100 mL 95% ethanol and 75g of NaCl) were added and stirred. Afterward, 4mL of 1 N HCl and 5mL of 4% BaCl₂ were added at room temperature. The resulting suspension was maintained at 400°C in the bath for 15 min before dilution and analyzed by using (Spectrum lab 752, England) UV Spectrophotometer (at $\lambda = 420\text{nm}$).

Nitrate content determination

The nitrate content of (each) sample was determined by the Phenoldisulphonic method adopting Samira et al. (2009). First, the concentration of chloride in each sample was determined. Typically, 3 mL of (each) sample was measured from the stock solution into the centrifuge tube and 100 μ L of silver sulfate was added. The volume was made up to 10 mL with distilled water.

The tube was centrifuged for 10 min until the solution was clear. 5 mL of the clear solution was put in a glass evaporating dish, placed on a water bath at 50°C to evaporate to dryness, and cooled. Upon completion, 1mL of phenoldisulphonic acid was added. After 10min, 10 mL of water was added, transferred to 100 mL volumetric flask, and was made alkaline by the addition of 2 mL conc. NH₄OH followed by thorough mixing. The absorbance at 410 nm was measured by using a UV/ Visible Spectrophotometer; (Spectrum lab 752, England).

Heavy metal determination

0.5 g of (each) sample was accurately weighed into a clean digesting flask and a 20 mL mixture of concentrated HCl and HNO₃ (1:3, v/v) was added. The flask and content was heated gently in a fume cupboard for 5 minutes at 145 °C and allowed to cool before filtering through a No. 42 Whatman filter paper into a 50mL volumetric flask (Perihan and Kurt 2012). The digestion flask was rinsed 3 times with 5 mL double distilled water and was added to the content of the volumetric flask before making to mark (Harrad et al. 2008). The digest was analysed for Co, Cd, Cr, Pb, and Cu using Flame Atomic Absorption Spectrophotometer (FAAS) model Buck Scientific SVG 210.

Health risk assessment

Considering the amount of time spent indoor by students daily within campus, the average daily dose of exposure to heavy metals are estimated by three core exposure pathways –(i) ingestion (ii) inhalation (respiratory), (oral) and (iii) dermal contact(skin) (Luo et al. 2012, USEPA 2014)

$$ADD_{Ingestion} = \frac{C \times CF \times IRs \times FI \times EF \times ED}{BW \times AT} \quad (4)$$

$$ADD_{Inhalation} = \frac{C \times IRa \times ET \times EF \times ED}{PEF \times BW \times AT} \quad (5)$$

$$ADD_{Dermal\ contact} = \frac{C \times CF \times AF \times ABS \times EF \times ED \times EV \times SA}{BW \times AT} \quad (6)$$

Where the exposure factors for dose model (in adults) areas follow:

$$IRs = 30 \frac{mg}{day}; Exposure\ Frequency = 350 \left(\frac{day}{year} \right); Exposure\ Duration =$$

$$30\ years; Average\ Time(AT) = (ED \times 365)days; Body\ Weight\ (BW) =$$

171 70kg; Conversion Factor = $\frac{10^{-6}kg}{mg}$; Fraction Ingested (FI) =
 172 1; Inhalation Rate (IRa) = $7.63 \frac{m^3}{hour}$; Dermal Absorption Factor (ABS) =
 173 0.001; Adherence Factor (AF) = 0.07; Exposure Time (ET) =
 174 $14 \frac{hours}{day}$; Surface Area(SA) = 5700 cm²; Particulate Emission Factor (PEF) = 1.36 ×
 175 $\frac{10^9kg}{m^3}$; Event Frequency(EV) = 1 event/day (USEPA 2001; USEPA 2004; IRIS 2018)

176 **Non-carcinogenic risk assessment**

177 The non-carcinogenic effect canbe investigated by estimating the hazard quotient (HQ) and
 178 hazard index (HI) of each metal.

$$179 \quad HQ = ADD/RfD \quad (7)$$

$$180 \quad HI = \sum_{n=1}^n HQ = \sum_{n=1}^n \frac{A_i}{D_i} = \frac{A_1}{D_1} + \frac{A_2}{D_2} + \frac{A_3}{D_3} + \dots \frac{A_n}{D_n} \quad (8)$$

181 Where,

182 $A_1, A_2, A_3, \dots A_n$ is the average daily dose (ADD) of each metal in the mixture of n
 183 metal present in the samples through the different pathways (ingestion, inhalation or dermal
 184 contact) and $D_1, D_2, D_3, \dots D_n$ are the reference dose of each metal (USEPA 2001).

185 Generally, HQ and HI ≤1 implies no adverse effect while >1 indicates potential adverse effect
 186 (USEPA 2001; Li et al. 2018)

187 **Statistical analysis**

188 The data obtained in this study were subjected to statistical analysis using MS Excel. The
 189 arithmetic mean, range and standard deviation (SD) for the analysis of heavy metal
 190 concentration in the samples were determined (Yangbing et al. 2019). Correlation of variance
 191 (CV) = $\frac{SD}{Mean} \times 100$ was calculated to show the distribution pattern of the heavy metals
 192 and other parameters in the samples. ANOVA was also used to determine the distribution
 193 differences based on mean concentrations.

194 **Results and discussion**

195 **Results of physicochemical analysis**

The results of physicochemical properties (pH, conductivity; levels of anions) of the dust samples obtained from the four different universities -FUTA (represented as FU), FECA (represented as FE), OSCOHST (represented as HT) and ACE (represented as OA) are presented in Table 1. The alkalinity and acidity of indoor dust have been found to depend on the sources and seasonal variation (Wu et al. 2013). Although, sampling in this study was done during the dry season which have dustier event thereby increasing the background pH of the indoor dust. From the study, the pH ranges from 6.39-7.13 with the minimum value in the sample obtained from HT and maximum from FU; they are within neutral pH. This accounted for the low concentration of acidic oxides found in the samples. Furthermore, there is similarity in the results obtained with that obtained by Wu et al. (2013) for similar study in Lanzhou China at different seasons: spring (6.87) and summer (6.81). Consequently, the findings showed that the conductivity of the sample increases from 232 to 348. This show a wide variability compared to the pH values. However the trend observed in the study sites was OA>HT>FE>FU.

NO₃⁻ content of 0.01 mg/L was estimated in FU, a sample from the Federal University of Technology, Akure while 0.02 mg/L was obtained in other samples (FE, HT and OA). Latif et al. (2008) reported a mean of 0.02 mg/L for nitrate composition of household dust in Malaysia, which is in agreement with the findings of the present study. Notably, inorganic ions are usually employed for pollutant source identification and apportionment studies in indoor dust (Hassan 2012). Indoor-outdoor exchange could be responsible for the reported nitrate values. However, indoor sources such as burning candles and incense, cooking, and smoking activities are to be considered as well (Schladitz et al. 2015).

The mean level of sulfate obtained was 0.07 mg/L, with least concentration(0.04 mg/L) in FU sample and highest(0.1 mg/L) sample from OA, following a decreasing trend OA >HT >FE>FU. These values are lower than that reported by Latif et al. (2008) in Malaysia with the mean value of 27.42 mg/L for sulfate composition of household dust. Cooking activities, cleaning agents and chlorinated tap water are sources of sulfate in indoor dust.

The percentage chloride concentration obtained ranged from 0.15 to 0.46, with a mean of 0.27. FU sample contains the highest mean concentration of chloride followed by FECA samples, College of Health Technology samples and College of Education samples in the order. The

major sources of chloride in household dust are detergents containing chlorides while sulphate and nitrate are mostly due to combustion activities within the indoor environment (Men et al. 2018). Anionic and cationic surfactants found in indoor dust are mainly from synthetic surfactants found in consumer products (Lau et al. 2014). Summarily, the mean levels of nitrates in all samples (0.01-0.02 mg/L) are less than the mean of sulfate (0.04-0.10 mg/L) and %chloride (0.15-0.460). The level of the anion in this study corresponds with the level of such activities in the sample sites. However, all the values are lower than those reported by Latif et al. (2008) for anions in the stairway and other indoor dust samples. The sequence of concentration level was however as follows, $\text{Cl}^- > \text{SO}_4^{2-} > \text{NO}_3^-$.

TABLE 1

Heavy metal concentration in indoor dust

The selected heavy metal concentrations determined in the samples are shown in Table 2. Previous studies on indoor air quality showed that the composition of pollutants (heavy metals) in household dust depends on the indoor-outdoor interactions (Azmat et al. 2014; Gao et al. 2017).

For Lead (Pb), the mean concentration was obtained in the range of 0.02- 0.11 mg/kg with the highest in-dust sample from FECA and least in FUTA. The overall mean concentration of Pb was calculated to be 0.0625 mg/kg and is in the range of values reported by Olatunde et al. (2016) on the levels of the metal in indoor dust around tertiary institutions. The concentration of Pb was also found to be slightly lower than reported data from neighboring African city, Ketu, Ghana (Addo et al. 2012), and even from similar sites in Lagos State, Nigeria (Popoola et al. 2012). The relatively low concentration for Pb could be ascribed to a low level of industrial activities around the study area and as well ban on the use of lead (Pb) as additive in fuel and pigments in paints. Hence, low tendencies from anthropogenic actions. Additionally, the Pb concentrations were fairly uniform and fell below 0.1 mg/kg except for sample collected from FE (0.11 mg/kg). This could be as a result of the very old building of the collection site, causing the paints to peel and settle on the floor as specks of dust. This showed that gloss and emulsion paint use in Nigeria consists of substantial levels of Pb (Rashed 2008).

The concentrations of cadmium (Cd) were below the detection limit (ND) for the FU sample while the Cd concentration detected in the other samples was between 0.01- 0.02 mg/kg, which were lower than the average concentration in the earth's crust (Adekola and Dosunmu 2001). The value obtained in this study is relatively low compared with 0.175 – 0.722 mg/kg and 0.12 – 0.380mg/kg reported by Rashed (2008) and Adekola and Dosunmu (2001) respectively. Even though cadmium is carcinogenic and can damage the blood vessel system, the Cd concentrations obtained in this study were below permissible level and hence there is however little/no need to worry.

The mean concentration of chromium (Cr) in the dust samples is 0.185 mg/kg and a range of 0.12 – 0.25 mg/kg. Samples collected from FECA (FE) had the highest Cr concentration with those from College of Health Technology (HT) as the least. The mean value of chromium is thus higher than that obtained for cadmium and lead. Dust from the sample sites is, therefore, more exposed to chromium sources than lead or cadmium sources. These values are however lower than 17.37 mg/kg (Popoola et al. 2012). Chromium is used in alloys, electroplating, pigments, and paint manufacture (Kang et al. 2011). Automobiles and electronic waste are sources of metallic chromium in the environment (Musa et al. 2009).

Zn is one of the most spread elements in the earth's crust (air, soil, and water) (Musa et al. 2009). It fastens to dust particles and settles as Zn dust particles. The mean concentration of Zn was in the range of 0.11– 0.25 mg/kg with a mean of 0.21 mg/kg, which is higher than the levels of chromium, lead, and cadmium discussed above. This indicates that the environments were exposed to more zinc sources. Additionally, the level of Zn was highest in OA, a sample collected from Adeyemi College of Education, and least in HT, a sample from the College of Health Technology. The natural range of zinc in soils is 10 – 300 mg/kg (Musa et al. 2009), while in indoor dust; it is expected to be lower than that. The concentrations of zinc were within these natural ranges and are significantly smaller than those reported in other studies. For example, a range of 4 - 42 mg/kg was reported by Eneji et al. (2015).

The average concentration of copper obtained was 0.23 mg/kg, which is higher than the mean of each of the other metals. However, the values fall within the range 0.18- 0.31 mg/kg with highest in FE, a sample from FECA and lowest in OA, a sample from the Adeyemi College of

Education. The values were lower than the range 0.190 – 1.990 mg/kg (Adekola and Dosumu 2001), 5.65 – 11.30mg/kg (Samson 2019) and 2.20 – 14.00mg/kg (Wahab et al. 2012). The high level of copper-plated utensils and copper wires used in homes is the major sources of copper in environmental medium and indoor dust (Kim et al. 2015). However, learning difficulties, antisocial and hyperactive behavior among others are the adverse health effects of high copper exposure (Kim et al. 2015). Generally, all the metals investigated (Cu, Pb, Cd, Cr, and Zn), were found to be relatively below the permissible level of heavy metals in indoor dust (Olatunde et al. 2016).

TABLE 2

Estimation of the calculated average daily dose

Estimation of the calculated average daily dose

The estimation of calculated average daily dose (ADD) of heavy metals in each dust sample is presented in Figure 1. The average daily doses (ADD) of heavy metals were determined based on exposure via ingestion, dermal contact and inhalation denoted as ADD_{ing} , ADD_{derm} and ADD_{inh} respectively. Selection of these higher institutions within the state was based on their proximity to more anthropogenic actions such as industrialization, urban construction, and automobile movement among other parameters. From Figure 1, the trends observed for the average daily exposure dose in the study were in the order $ADD_{ing} > ADD_{derm} > ADD_{inh}$, which implies that ingestion is the major pathway of exposure with inhalation the least. This is similar to other studies (Izhar et al. 2016; Gope et al. 2017). However, the ADD of the heavy metals followed the decreasing order $Cu > Zn > Cr > Pb > Cd$ for various pathway. Values reported are lower than the ADD reported for a similar study in Lagos state primary school, Nigeria by Olatunde et al. (2016).

FIGURE 1

Non-carcinogenic risk of heavy metals in indoor dust

The non-carcinogenic risk of the studied metalss was assessed via the three exposure pathways considered in the present work using the hazard quotients (HQ) and hazard indices (HI) of metal intake from the samples. HQ and HI were determined as presented in Table 3. The calculated HQ ranged from 3.93×10^{-10} to 5.920×10^{-5} . The trend in the HQ obtained from the study sites was in the order $FE > OA > HT > FE$. However, the magnitudes of the HQ were below 1×10^{-4} . Consequently, remediation of the study sites is not needed (Zheng et al. 2010a). It was observed that for most of the study sites that the HI reported for the metals was $Cr > Pb > Cd > Cu > Zn$. The results were at variance with previous report $Pb > Cd > Zn > Cu > Cr$ for street dust (Hu et al. 2011). Generally, the HQ and HI reported are less than 1 respectively, which implies there is no potential non-carcinogenic effect in the sites, indicating no health risk for the students and their tutors (IRIS 2018)

Conclusion

This study reveals that the variations in the heavy metal composition in indoor dust of the study site are below the permissible level. Also, study showed that no health risk associated is associated with 3 exposure pathways. Consequently, the HQ and HI reported was relatively less than 1, which implies no potential non-carcinogenic human health risk. Hence, there is no constant concentration of a particular pollutant in environment; frequent monitoring of the quality of the indoor dust in this academic environment should be recommended. More so, efforts and regulations should be in place to maintain this status quo of non-contamination of these areas of studies.

Declaration

Ethical Approval

The study do not involved experimentation on animals or man.

Consent to participate

N/A

Consent to Publish

All authors gave their approval for the manuscript publication.

Author's contribution

OOA conceptualized the idea and was involved in performing the experiments, writing, reviewing and editing the original draft. ATA, AO and TOO were involved in formal analysis and writing of the original draft preparation; AMA and OBO reviewed and edited the work. JIO involved in supervision, wrote, reviewed and edited the original draft.

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Competing Interest

All authors have no conflict of interest to disclose.

Availability of data and materials

This data herein are original research work and has not been submitted for publication elsewhere.

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498 **Table1: Physicochemical properties of the indoor dust samples**

Parameters	Samples				Range
	FU	OA	HT	FE	
pH	7.05±0.17(2.41)	7.09±0.12(1.69)	6.39±00(0)	7.13±0.04(0.56)	6.39-7.13
Conductivity	232±9.49(4.09)	348.20±6.22(1.79)	314.20±6.61(2.10)	270.80±8.96(3.3)	232-348.20
NO₃⁻ (mg/L)	0.01±0.00(0)	0.02±00(0)	0.02±00(0)	0.02±0.0(0)	0.01-0.02
SO₄²⁻ (mg/L)	0.04±0.01(25)	0.10±0.01(100)	0.06±0.01(16.67)	0.08±0.01(12.50)	0.04-0.10
%Cl⁻	0.460±0.07(15.22)	0.15±0.04(26.67)	0.18±0.03(16.67)	0.28±0.06(21.43)	0.15-0.460

Results were expressed as Mean ± SD(CV) for three independent samples (n=3)

Location of sample: FU: Federal University of Technology, Akure; FE: Federal College of Agriculture; HT: Ondo State College of Health Science Technology; OA: Adeyemi College of Education

499

500 **Table 2: Mean concentrations of heavy metals in indoor dust (mg/kg)**

Parameters	Samples				Range
	FU	OA	HT	FE	
Pb	0.02±0.01(50)	0.07±0.03(42.89)	0.05±0.03(60)	0.11±0.03(27.27)	0.02-0.11
Cd	ND	0.01±0.00(0)	0.01±0.00(0)	0.02±0.01(50.00)	ND-0.02
Cr	0.170±0.05(29.41)	0.20±0.12(60)	0.12±0.07(58.33)	0.25±0.18(72.00)	0.12-0.25
Zn	0.230±0.09(39.13)	0.25±0.13(52)	0.11±0.04(36.36)	0.24±0.10(41.67)	0.11-0.25
Cu	0.200±0.16(80)	0.18±0.08(1.44)	0.24±0.15(62.50)	0.31±0.11(35.48)	0.18-0.31
Total metals	0.620	0.710	0.53	0.93	0.620-0.93

Note: ND denoted not detected

Results were expressed as Mean ± SD(CV) for three independent samples (n=3)

Location of sample: FU: Federal University of Technology, Akure; FE: Federal College of Agriculture; HT: Ondo State College of Health Science Technology; OA: Adeyemi College of Education

501

Note: ND denoted not detected

Location of sample: FU: Federal University of Technology, Akure; FE: Federal College of Agriculture;

HT: Ondo State College of Health Science Technology; OA: Adeyemi College of Education

Figure 1: Estimated average daily dose of heavy metals in the dust samples

Table 3: Hazard quotient (HQ) and Hazard index of heavy metal in the dust samples

Exposure pathway	Sample	Pb(10^{-8})	Cd(10^{-8})	Cr(10^{-8})	Zn(10^{-8})	Cu(10^{-8})	HI(10^{-8})
Ingestion							
	FU	235	ND	2330	31.5	222	2820
	OA	823	411	2740	34.3	199	4210
	HT	586	411	1640	15.1	266	2920
	FE	1290	822	3430	32.9	342	5920
Inhalation							
	FU	0.615	ND	6.10	0.0823	0.580	7.38
	OA	2.15	1.08	7.17	0.0897	0.523	11.0
	HT	1.54	1.08	4.30	0.0393	0.695	7.65
	FE	3.38	2.15	8.97	0.0860	0.9	15.5
Dermal contact							
	FU	3.12	ND	30.9	0.420	2.94	37.4
	OA	10.9	5.46	36.3	0.457	2.65	55.8
	HT	7.80	5.46	21.8	0.2	3.53	38.8
	FE	17.2	10.9	45.7	0.437	4.56	78.8
Reference dose (RfD) of heavy metals via ingestion: Pb=3.5E-3; Cd=1.0E-3; Cr=3.0E-3; Zn=3.70E-2; Cu=0.30							
Reference dose (RfD) of heavy metals via inhalation: Pb=3.52E-3; Cd=1.0E-3; Cr=2.86E-5; Zn=4.02E-2; 0.30							
Reference dose (RfD) of heavy metals via dermal contact: Pb=5.25E-4; Cd=5.0E-3; Cr=2.5E-4; Zn=1.90E-3; 6.0E-2							
Note: ND denoted not detected							
Location of sample: FU: Federal University of Technology, Akure; FE: Federal College of Agriculture; HT: Ondo State College of Health Science Technology; OA: Adeyemi College of Education							

Figures

Figure 1

Estimated average daily dose of heavy metals in the dust samples Note: ND denoted not detected
Location of sample: FU: Federal University of Technology, Akure; FE: Federal College of Agriculture; HT: Ondo State College of Health Science Technology; OA:Adeyemi College of Education